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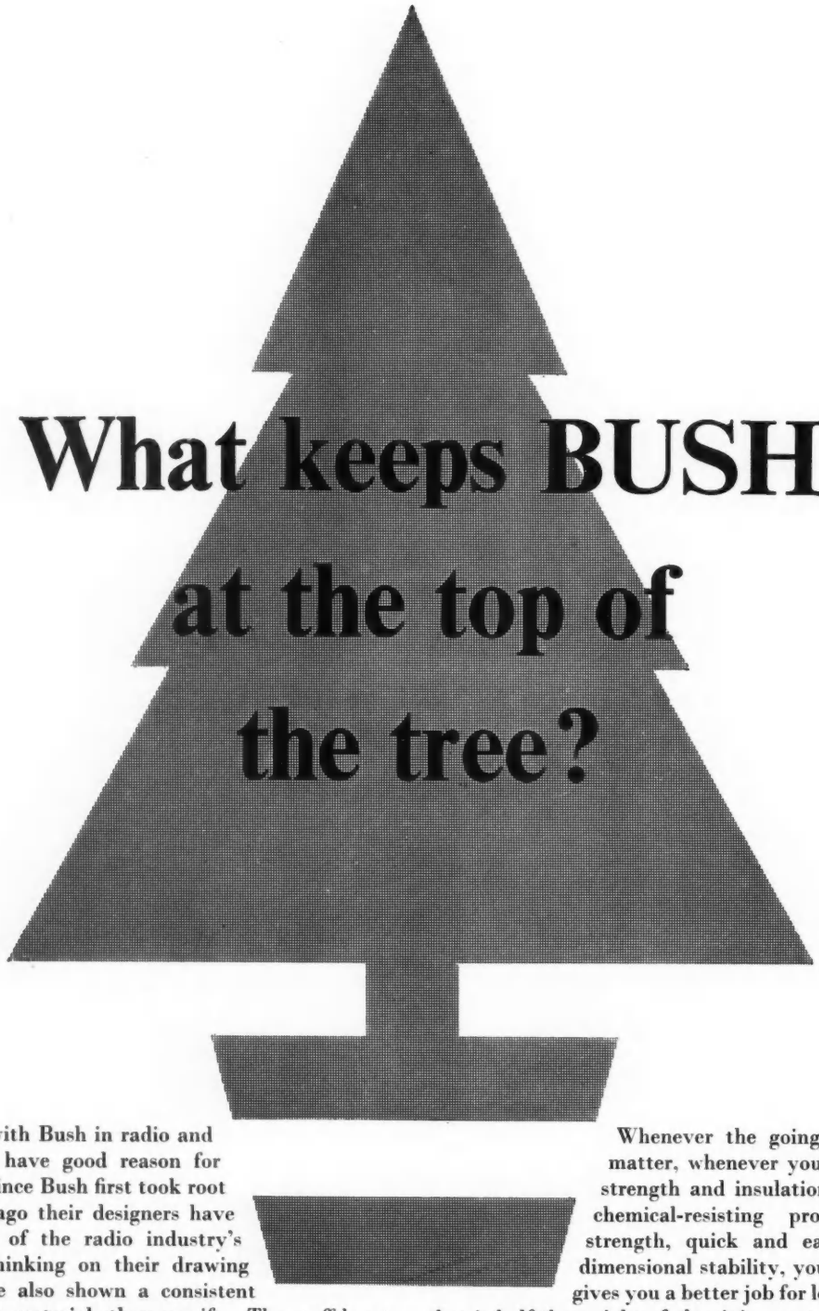

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CONTROL VALVES FOR HIGH AIR-MASS FLOWS.

By F. E. SWAIN.

In certain industrial applications, and particularly in current and projected gas-turbine engine research and test plant employing high air-mass flows at pressures ranging from 1 to 20 atmospheres, some interesting and novel problems arise in the design and production of suitable air-control valves. The hitherto accepted forms of hydraulic sluice-valve units, employing the parallel or wedge form of valve, though suitable for duties within the limitations for which they were designed, have been found to be impracticable in installations where high pressure and high mass flows are entailed.

Pipelines ranging from 1 ft. to 5 ft. in diameter are to-day being employed to cope with the high air-mass flows required in modern aero-engine test plant and, when one considers the large cross-sectional area of the movable valve member exposed to air pressure, it will be apparent that the resulting mechanical load between the movable valve and its seating is of an extreme order. It is of particular interest to note that, of all the various production designs of large-diameter valves available to-day, the maximum guaranteed pressure rating diminishes rapidly as the pipe diameter increases. The reason for this is not far to seek, in that the movable valve member is unbalanced in terms of fluid pressure. To quote an example: the mechanical load arising from 100 lb. per square inch fluid pressure applied to a valve member 36 in. in diameter reaches some 50 tons. Such extreme loadings between the critical sealing surfaces of the valve cannot be countenanced if ease of operation and useful working life are sought.

A considerable amount of research and development work has been carried out by David F. Wiseman and Sons, Limited, 145, Conybere-street, Birmingham, 12, and the writer is now able to explain the main line of research followed in seeking a solution. Various forms of control valves were reviewed, falling under the general categories of slide valves, butterfly valves, and rotary valves. Two main types were selected which appeared to offer the more promising results, the first of which (a type of butterfly valve) is shown in Figs. 1 to 3.

The butterfly valve has much to commend it on the score of simplicity, but the normal form of oblique or transverse movable member does not lend itself to adequate sealing characteristics at the periphery of the valve, even if the most careful workmanship and precision are ensured. To overcome this inherent defect, it was decided to employ an offset seating, as shown at *a* in Fig. 1. It will be seen that two main control levers are employed; lever *b* moves the valve through 90 deg., while lever *c* moves the valve off or on to its seat through the medium of a simple eccentric *d*. In the closed position, the butterfly serves as an effective poppet valve pressed against the circular seating, the angle of which is at a tangent to the circle through which the butterfly swings. Prototype tests reveal that air pressures of 150 lb. per sq. in. can be held with no leakage area.

This is a simple and effective unit, the low valve-seat loading being ensured by the design of the valve and being independent of the prevailing fluid pressure. Nevertheless, the pressure rating of this valve is undoubtedly limited by the ability of the two spindle bearings each to carry the maximum loading of about 100 tons. Furthermore, when used as a control valve, the torque loadings on the lever *b* operating the butterfly have been found to be variable and sometimes extreme. Development is still proceeding for certain specific duties where sensitive control is the major requirement. General-purpose positive stop valves and relief valves suitable for pipe-line bores ranging from 9 in. to 36 in. in diameter are now in production.

During the investigations it became apparent that the ideal sensitive control arrangement could best be achieved by balancing out such extreme mechanical loadings. Accordingly, it was decided to investigate the possibilities of the novel form of valve shown in Figs. 4, 5 and 7. Here, an attempt was made to balance the valve members by means of the fluid in such a way that axial loadings between the two independent valve members *e*, *f* and the sandwich seating *g* is reduced to the minimum and maintained irrespective of the air pressure

Fig. 1. SECTION A-A — 18 IN. DIA. "TANSPHERE" VALVE.

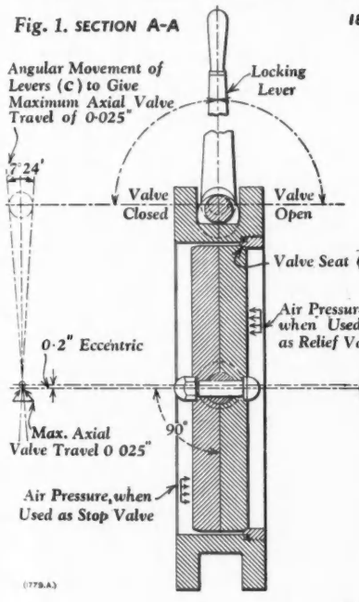
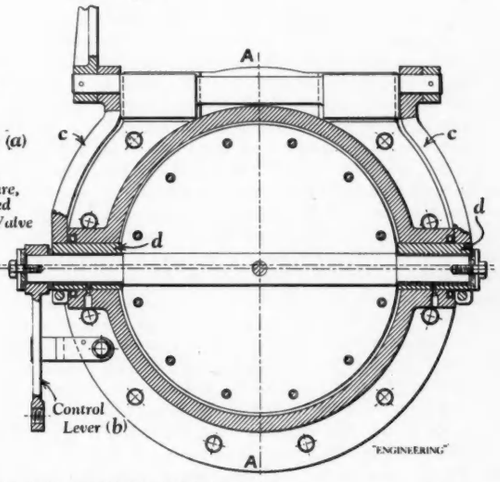


Fig. 2.



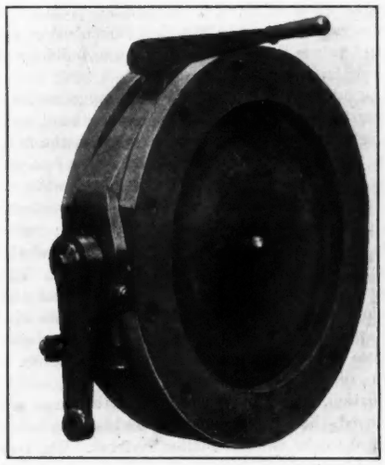


FIG. 3. "TANSPHERE" BUTTERFLY VALVE.

SENSITIVE BALANCED CONTROL VALVE.

Fig. 4. HALF SECTION B-B SHOWING ACTUATING GEAR.

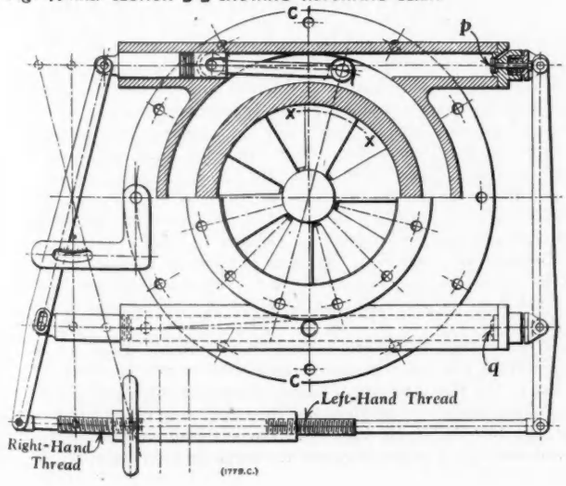


Fig. 5. HALF SECTION C-C

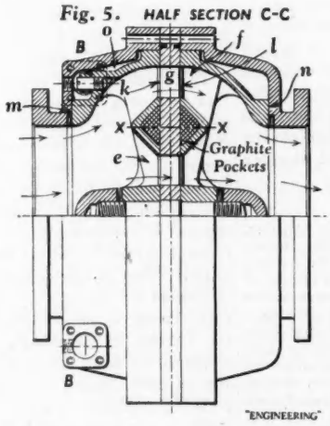
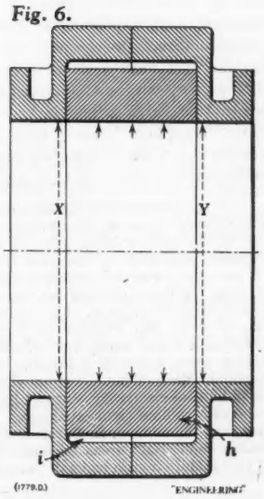


Fig. 6.



in the pipe-line. The theory of balance may be understood from Fig. 6. Diagrammatically, we have a cored member *h* rotatably mounted in an annulus *i* in the pipe bore. Static pressure within the pipe would result in radial fluid loading on member *h*, but that member would not be subject to axial loading, provided entry area X is equal to outlet area Y. In short, member *h* would be fluid balanced both axially and radially.

The same conditions would prevail in respect of valve member *e*, shown in Figs. 8 and 9, provided, again, that the entry area X is equal to the sum of the exit areas Y. Reverting to Figs. 4 and 5, it should be noted that the two independent valve members *e*, *f* are axially and radially balanced whether the valve be open or shut, irrespective of the fluid pressure prevailing. The mechanical loading between the two seatings is predetermined by adjusting nuts and spring media sufficient to form a dual fluid seal.

The two flat valve seats are carefully lapped and graphited to form effective seals at *k*, *l*. Slight axial clearances *m*, *n* are provided at the end of each rotatable valve member, simple face seals being employed to minimise fluid leakage at these points. Any slight leakage past these seals will result in a build-up of air pressure in casing *o*, tending to destroy the desired fluid balance and thus imposing a higher mechanical load at the valve seatings. Whereas a heavy valve-seat loading is permissible when the valve member is stationary (and is, in fact, desirable to prevent radial valve flutter), it is essential to eliminate heavy loading at the time of valve operation. This requirement is achieved by automatic operation of release valves *p*, *q* prior to radial movement of the control valves themselves, venting any build-up of pressure in casing *o* to atmosphere.

The advantages of this form of valve may be summed up as follows: the cross-sectional area throughout the valve remains constant in the fully open position; fluid turbulence is reduced to the minimum; operating loads are light; loading at the valve seats remains approximately constant; two independent valve seats are employed; valve seats masked in the fully open position; and the symmetrical design, facilitating installation. The valve has been subjected to considerable test and development, both hydraulically and pneumatically, and arrangements are in hand to produce special-purpose valves ranging from 12 in. to 36 in. bore.

No difficulties are envisaged in large-scale production, since only three main castings are employed, the critical machining and lapping being confined to the two flat sealing surfaces. The two distinct types of valves described, developed primarily to handle air, clearly have a wider application. The butterfly stop valve in particular has much to commend it, with its positive sealing characteristics, compactness and relatively low cost of manufacture. Its compactness may be gauged from the fact that a 36-in. bore valve measures only 9 in. between the attachment flanges. Various sizes of this valve, which is known by the trade name "Tansphere," have been installed at the National Gas Turbine Establishment and at other gas-turbine test plants in this country.

ELECTRICITY-SUPPLY STATISTICS.—During October, 1953, 5,299 million kWh were sold by the British Electricity Authority to the Area Boards, an increase of 5 per cent. over the output in the same month of last year. When corrected for the weather and the number of working days, the increase was, however, 7·4 per cent., the weather conditions having been warmer and there being less effective working days than a year ago. In addition, the reversion to Greenwich Mean Time occurred three weeks earlier. The amount of electricity sent out by the Area Boards was 5,046 million kilowatt-hours, which was also 5 per cent. more than in October, 1952. Supplies to "mainly industrial" areas increased by 4·8 per cent., and to "mainly non-industrial" areas by 4·2 per cent.

CONTROL VALVES FOR HIGH AIR-MASS FLOWS.

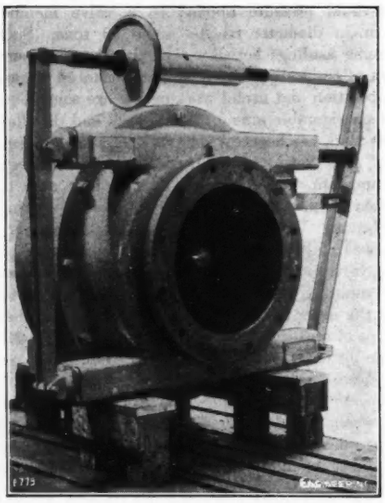
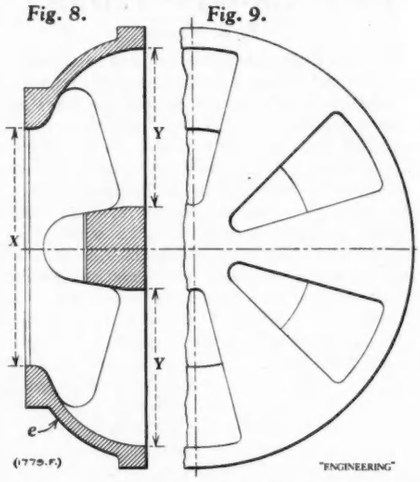


FIG. 7. ROTARY VALVE.

Fig. 8. Fig. 9.



LITERATURE.

Vermuyden and the Fens.

By L. E. HARRIS. Cleaver-Hume Press, Limited, 42a, South Audley-street, London, W.1. [Price 21*s.* net.]

THE name of Cornelius Vermuyden is a familiar one to engineers, especially to civil engineers and to those mechanical engineers who are interested in pumping plant for drainage or reclamation works. They may not talk about him very much (if they are English engineers) because most Englishmen hesitate to bring into their conversation foreign names that they are not sure how to pronounce; and, moreover, many engineers who have heard of Vermuyden would be puzzled to list the works that he undertook in England, and the sequence of the associated events. Mr. Harris has been wise, therefore, in giving his book the attractive general title of *Vermuyden and the Fens*, with the more specific sub-title, "A Study of Sir Cornelius Vermuyden and the Great Level." What he does not mention in his foreword, though the details are of some significance, is that he is a chartered mechanical engineer by profession, with a long experience of pumping plant for fen drainage, and that, as a member of the Council of the Newcomen Society, he is also well aware of what is required to produce a dependable piece of historical research. His book may be accepted, therefore, as an authoritative study, even without the numerous references to the original documents that he has personally consulted and the support that he acknowledges from experts in England and the Netherlands.

The purpose of the book, as the author states, is "to present a critical assessment of Vermuyden's work . . . based primarily on that work in the Great Level, on a new interpretation of contemporary records, and on the use of some contemporary records which have hitherto been neglected." Vermuyden was a Zeelander, born in 1590 in the town of St. Maartensdijk, in the island of Tholen. It seems probable that his first visit to England was in 1621, when he was engaged by the Commissioners of Sewers for the county of Essex in connection with repairs to the breach in the north bank of the Thames at Dagenham. Subsequently he was employed by King James I to drain Windsor Park and—a much bigger undertaking—the Crown property of Hatfield Chase, near Doncaster. At the outset of this work he took out naturalisation papers as an English citizen. On January 9, 1628-29, Charles I conferred on him a knighthood, and a year later he was engaged by Francis, fourth Earl of Bedford, as engineer for the drainage of the Great Level of the Fens.

The task that Vermuyden undertook, and which occupied him for the next 23 years, was essentially similar to the work that he had done in Hatfield Chase; it was the problem of dealing with "winding tortuous rivers with small gradients, endeavouring to find a way through a flat expanse of land to their outfalls," in this case into the Wash. He was also faced with the difficulty, which did not arise in the previous instance, of keeping the outfalls clear. He solved the first problem by cutting the Bedford River, 21 miles long and 70 ft. wide, from Earith to Denver, thus providing the Great Ouse with a straight course, to supplement its natural winding course. This in itself was not sufficient, and eventually Vermuyden had to cut the Hundred Foot River, parallel with the Bedford River and to the east of it, and joining the Ouse at Denver Sluice; though the idea of constructing Denver Sluice, it would seem, did not originate with him. To review all the arguments for and against the completed scheme would be quite impracticable in a brief notice—Mr. Harris discusses them at length, and to his pages the reader must be referred; but it is interesting to note, from the two outline maps reproduced on page 137 of his book, how closely Vermuyden's scheme of 1642 resembles that put forward by Sir Murdoch Macdonald, in 1949.

Vermuyden's connection with the Great Level came to an end in 1655, when he had his last meeting with the Bedford Level Adventurers, whose archives, now in the possession of the Great Ouse River Board, have provided Mr. Harris with so much valuable material; but he lived for 22 years more, and the two concluding chapters of the book attempt to throw some light on the relative obscurity surrounding the latter part of his life. If the attempt is not entirely successful, that has certainly not been due to any lack of industry on the part of the author, whose researches have ranged over a very wide field. He has succeeded, however, in finding in the parish register of St. Margaret, Westminster, the record of the burial of "Sr. Cornel[s] Vermooden" on October 15, 1677; which, as he observes, "gives us conclusively the last record of that remarkable man," and demolishes the legend, started by an ill-informed correspondent in *Notes and Queries* in 1877, that he was buried in St. Martin-in-the-Fields in 1683. There are still gaps in the story of Vermuyden to occupy the attention of historians in future years, and they may yet be filled, but they detract in no way from the credit due to Mr. Harris for his excellent study of a civil engineer who certainly deserved it.

THE VIBRATIONS OF MACHINE-TOOL STRUCTURES.

By S. A. TOBIAS,* Ph.D., and W. FISHWICK,* Ph.D.

THE vibrations observed in machine-tool practice are normally due to one or more of the following causes: (*a*) out-of-balance of rotating machine components; (*b*) self-induced vibrations due to the cutting action; (*c*) vibrations from other machines transmitted through the foundation; (*d*) free damped vibrations due to hammer blows, sudden change of velocity, etc. The type of vibration produced by (*a*) and (*c*) is a forced vibration. Free damped vibrations are confined mainly to certain types of machines, such as presses and hammers, and are of relatively small importance owing to the considerable damping capacity of most structures.

Every structure when set into vibration by a suddenly applied force, such as a hammer blow, will vibrate with a number of distinct frequencies: the so-called natural frequencies. Vibrations of large amplitudes are induced in a structure only by harmonically varying forces the frequency of which is equal to, or nearly equal to, one of the natural frequencies. In the case of equivalence it is said that the structure is in resonance. With the exception of out-of-balance forces, most exciting forces occurring in machine tools are not harmonic, but only periodic. Since, however, every periodic force can be analysed into its Fourier components, which themselves are harmonic, resonance occurs if the frequency of any of these components is equivalent to any of the natural frequencies.

The amplitude of vibration of a structure when at resonance depends partly upon the amount of vibrational energy fed in and partly upon the damping capacity of the structure. The larger the damping the more vibrational energy will be absorbed and the smaller the resulting amplitude. The damping capacity of welded structures is in general, greater than that of cast structures.† Damping can also be increased by various artificial means, such as vibration-absorbing materials and damping devices. Furthermore, it has been observed that by a suitable distribution of stiffening ribs the absorption of vibrational energy can be facilitated.

Based upon these facts the normal procedure to develop vibration-free machine-tool structures is to design them in such a way that the frequency of possible exciting forces should be far away from any of the natural frequencies and the greatest amount of damping should be introduced. It is normally attempted to keep the exciting frequencies far below the natural frequencies. In practice this can be achieved only in the case of small machines and consequently a compromise is reached by placing them between the natural frequencies. This procedure will safeguard only against vibrations due to out-of-balance forces. Self-induced vibrations will make the structure vibrate at its natural frequencies and so it appears that the only way to keep them under control is to raise the natural frequencies as high as possible and to introduce the maximum amount of damping. The natural frequencies of simple structures can be calculated to a close approximation either by reducing them to elementary mass-spring systems or by using Rayleigh's method.* In most cases, experiment and theoretical considerations have to go hand in hand to ensure that vibrations of undesirably large amplitudes will not occur.

It has been noted that structures which had been designed with due consideration to their vibrational behaviour and gave satisfactory performance from this point of view on the test stand of the manufacturing firm showed different vibrational characteristics when installed at the customer's works. In most cases, their performance from the point of view of vibrations seemed to have improved, but in others amplitudes of greater magnitude than originally contemplated were noted. Since the only factor which had been changed was the foundation and the method of mounting the machine, it was inferred that these must have altered the natural frequencies of the structure and/or their capacity to transmit or absorb vibrational energy must have differed from those under which the machine was originally developed and tested.

TABLE I.—SUMMARY OF EXPERIMENTAL RESULTS.

—	Method of Supporting Base-Plate.	Concrete Floor.		Wood-Block Floor.	
		Resonance Frequency.	Damping Factor.	Resonance Frequency.	Damping Factor.
A	Three steel blocks (size 3 in. by 4 in.)	2,250	0·096	2,340	~0·125
B	Eight steel blocks	4,220	0·270	4,100	0·228
C	Directly on the floor	3,850	>0·3	4,630	>0·3
D	Three felt pads (size 4 in. by 6 in. by ½ in., three layers at each point)	1,180	0·160	1,300	0·093
E	Eight felt pads (one layer at each point)	1,880	0·258	3,100	~0·332
F	Three rubber pads (size 5 in. by 6 in. by ½ in., three layers at each point)	620	0·056	630	0·037
G	Eight rubber pads (one layer at each point)	1,560 (1,970)	0·133	1,770	0·202

The object of the present investigation was to elucidate the effect of the foundation and the method of mounting upon the vibrational characteristics of machine-tool structures. For this purpose, the forced vibrations of a heavy radial drilling machine base-plate were investigated for seven types of mountings upon two kinds of workshop floors. The weight of the base-plate was 44 cwt. and its dimensions were 117 in. by 43 in. by 10 in. It was realised at the outset that the plate was of exceptional stiffness compared with most machine-tool structures and that consequently its natural frequencies would be relatively high. Thus, the absolute values of the natural frequencies were of no interest, the aim being to observe whether certain types of mounting and floors result in a higher natural frequency and a greater damping factor than others.

The investigation was carried out on an ordinary concrete floor (Series I) and on a floor consisting of wood blocks resting upon 3 in. of concrete (Series II). The seven ways in which the machine was set up are indicated in Table I. The object of experiment A was to determine the natural frequency of the plate for freely-supported ends. Hence, two steel blocks were placed at the corners of one end and the third at the middle of the other end. This method of mounting is of practical importance since it is customary to support high-accuracy machines (fine boring machines and grinding machines) at three points to avoid a distortion of the bed. Apart from these practical considerations, experiments A, D and F were considered to be suitable for the determination of some of the fundamental qualities of steel, felt, and rubber as mounting materials owing to the simplicity of the mode of vibration induced. In the case of experiments B, E and G the steel, felt and rubber pads, respectively, were placed in such a way that one was at each corner and two along each of the long sides, dividing the length into three equal parts. The height of the steel blocks was adjustable and contact with the plate at all eight points was ensured.

The forced vibrations of the base-plate were induced by an out-of-balance flywheel which was attached to the spindle of a variable-speed direct-current motor with a rating of 1 h.p. at 3,000 r.p.m. The combined weight of the motor and flywheel was 61 lb. The speed of the motor was continuously variable between 0 and 5,000 r.p.m., thus covering the frequency range up to 80 cycles per second which is important in normal machine-tool practice. The exciting motor was bolted to 1 in. by 1 in. by 36 in. steel bars which, in turn, were bolted to the middle of the base-plate. The vibrations were measured with an inertia-type piezo-electric vibration pick-up. The amplitudes were read directly from the meter of the instrument which was calibrated to give the root-mean-square of the amplitude. The wave form of the forced vibration was watched on the screen of a cathode-ray oscilloscope. It was found that if the plate were resting upon all supports, only a small amount of the higher harmonics were contained in the wave form. At resonance, or near it, the vibration was pure harmonic.

For all experiments the same procedure was adopted. The vibration pick-up was attached to the plate immediately behind the exciting motor (point X in Figs. 2 and 4, page 708). The motor speed was increased in small steps from 0 to 5,000 r.p.m. and every time an amplitude reading was taken of the resulting forced vibration. These amplitudes were plotted as a function of the revolutions per minute of the motor, i.e., the exciting frequency, and gave the "out-of-balance response curves" of the structure. From the response curves the natural frequencies were easily determined. The plate was then set into forced vibration at resonance (unless stated otherwise) and its dynamic deflection curve was measured by moving the pick-up along its length and taking amplitude readings at intervals of 10 in.

The damping factor θ of the whole system, i.e., the base-plate, the supports and that part of the foundation which took part in the vibration, was determined from the out-of-balance response curves with the "resonance curve method." θ is defined by

$$\theta = \frac{1}{2\pi} \frac{\text{energy loss per cycle}}{\text{stored energy}}$$

and can be determined from the resonance curve by

$$\theta = 0{\cdot}577 \frac{\Delta f}{f_0}$$

where f_0 is the resonance frequency and Δf is the resonance curve breadth at half the maximum amplitude. The formula given for θ is strictly true for resonance curves only, i.e., on the assumption that the exciting force is constant over the frequency range investigated. For out-of-balance response curves the method gives approximate values only, since the exciting force is proportional to the square of the exciting frequency.

The experimental results obtained are given in Figs. 1 to 4, and are summarised in Table I. The out-of-balance response curves for the concrete floor are given in Fig. 1, and for the wood-block floor in Fig. 3. Fig. 2 represents the dynamic deflection curves for the concrete floor and Fig. 4 those for the wood-block floor. Considering experiments A, D and F (Table I and Figs. 1 and 3), it is found that in all three cases the natural frequencies were lower on the concrete floor than on the wood

* Respectively I.C.I. Research Fellow and Lecturer in the University of Edinburgh.

† O. Kienzle and H. Kettner, "The Vibrational Behaviour of a Cast and a Welded Lathe-Bed," *Werkstattechnik*, vol. 33, pages 229 to 237 (1939); Anton Heiss, "The Vibrations of Machine-Tool Structures," *VDI-Forschungsheft*, No. 429, 1949-50.

* D. Laugharne Thornton, *Mechanics Applied to Vibrations and Balancing*, Second Edition, 1951. Chapman and Hall.

VIBRATIONS OF MACHINE TOOL STRUCTURES.

Fig. 1. CONCRETE FLOOR.

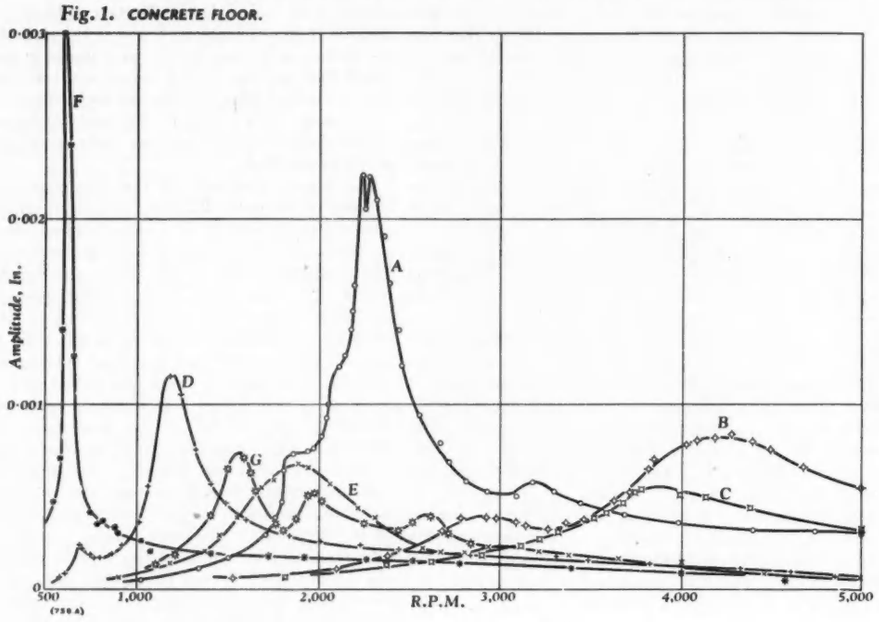


Fig. 2.
DYNAMICAL DEFLECTION CURVES.

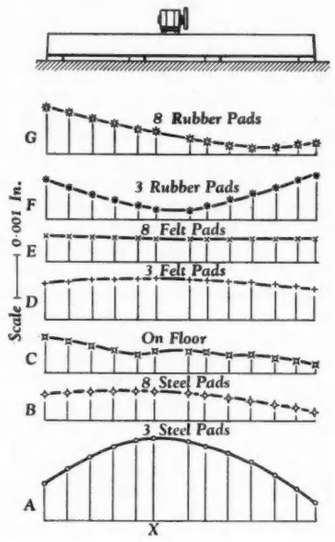


Fig. 3. WOOD-BLOCK FLOOR.

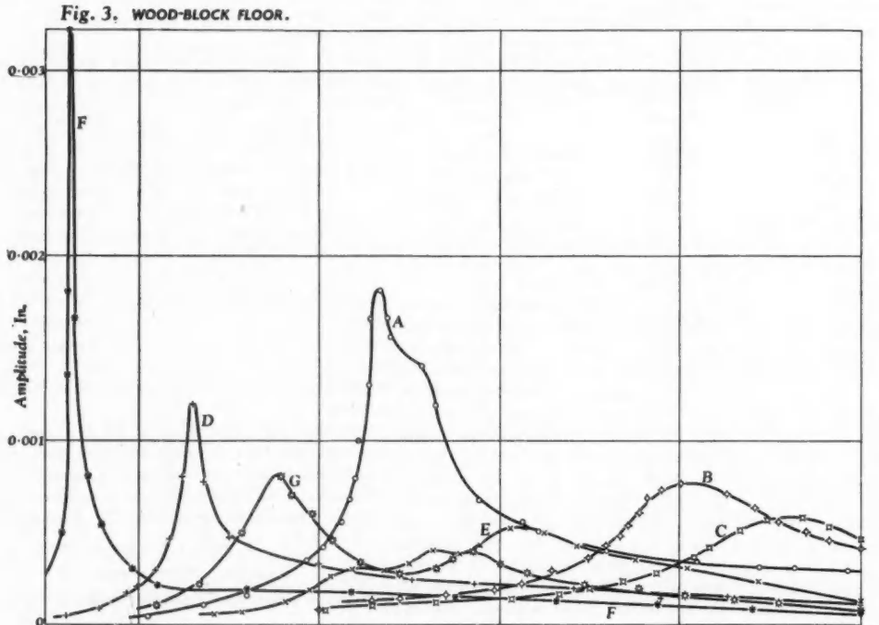
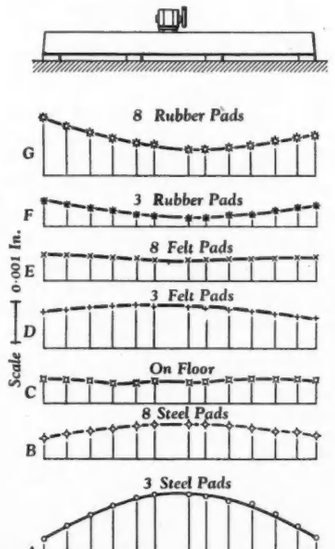


Fig. 4.
DYNAMICAL DEFLECTION CURVES.



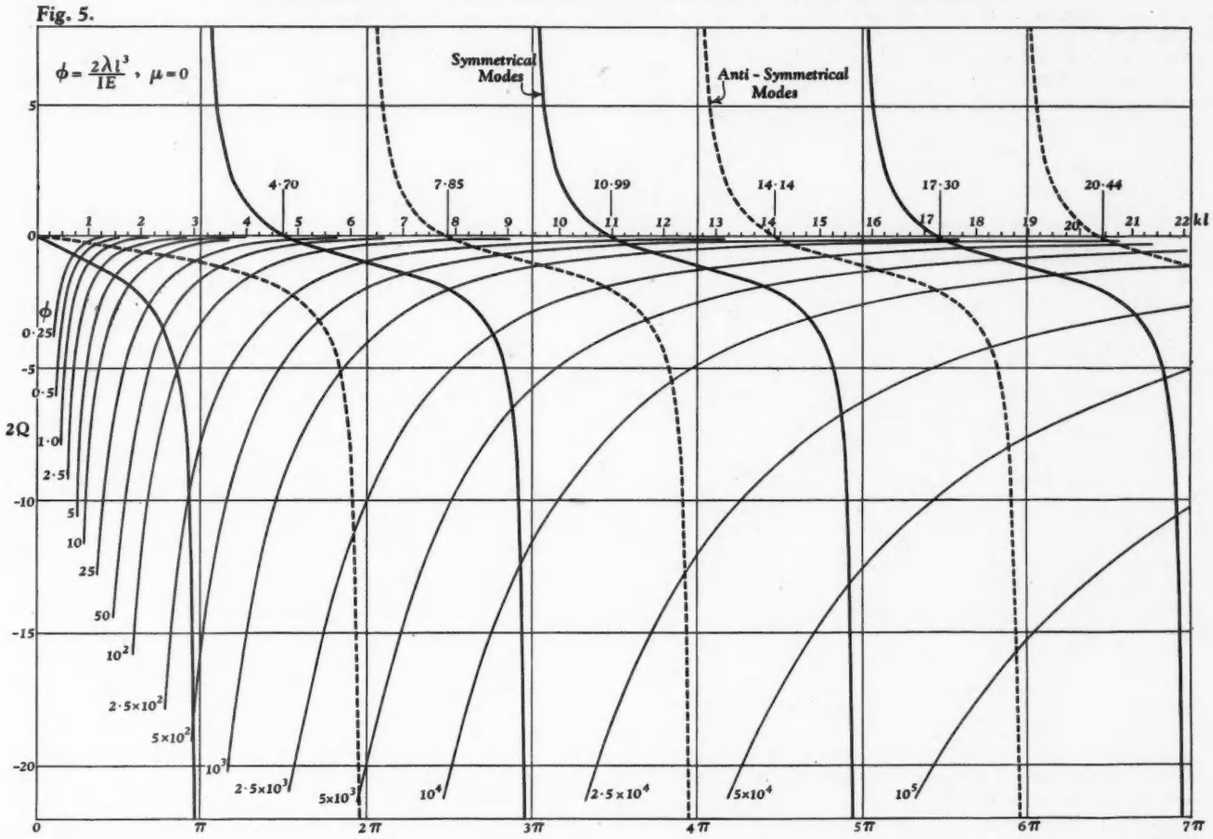
floor, the difference for F being, however, very small. F cannot be compared directly with A or D, as it represents a different type of vibration. The dynamic deflection curves (Figs. 2 and 4), for A and D show that the plate was bent into a parabolic shape, the maximum amplitude being in the middle where the exciting force was acting. In the case of F, it was found that at the resonance frequency of 620 r.p.m. and 630 r.p.m., respectively, the plate was not deformed at all, but moved up and down parallel with the floor with very large amplitudes (Figs. 1 and 3). As the exciting frequency was increased the amplitudes of the centre decreased (Figs. 1 and 3 represent the amplitudes of the point X of Figs. 2 and 4), but the amplitudes of the ends became larger; by increasing the exciting frequency the ends tended to flap. The natural frequency of this mode of vibration appeared to be above 5,000 r.p.m. The dynamic deflection curves for this experiment were measured at 2,000 r.p.m. Experiments B, E and G show that the introduction of eight supports increased in all cases the resonance frequencies and damping factors relative to the three-point supports of the corresponding mounting materials. Curve G for concrete had three comparatively high resonance peaks, the dynamic deflection curve being taken at the highest (1,560 r.p.m.). The variation of curve G for the wood-block floor is more consistent and indicates a considerably greater damping factor. The dynamic deflection curves show that the deformation of the plate was in all cases very much like that of the corresponding three-point supports, only the amplitudes were much smaller. Eight felt pads (curve E in Figs. 2 and 4) gave the smallest deformation of all types of mounting. When the plate was lying directly on the floor (curve C), there was another marked increase in the damping factor, and, for the wood-block floor, in the natural frequency as well. The dynamic deflection curves are intrinsically different from all the others, as they contained several inflection points.

From the point of view of the type of vibration investigated in experiments A, D and F, the base-plate can be regarded as a uniform beam of length l, cross-section A, mass $M = \rho A l$ and flexural rigidity IE. The ends are resting upon elastic supports which may be represented by an equivalent mass-spring system consisting of a mass m which is connected to the perfectly rigid foundation by a spring of stiffness λ (Fig. 9, page 711). The mathematical solution of this problem is given in the Appendix. At this place we shall refer only to those results which are of practical significance.

It is shown that the beam is capable of performing symmetrical and anti-symmetrical vibrations, that is, vibrations in which the ends move in phase or in

VIBRATIONS OF MACHINE TOOL STRUCTURES.

Fig. 5.



anti-phase, respectively, with equal amplitudes. The natural frequencies of the symmetrical vibrations are determined from

$$2\,Q = -\tan\frac{k\,l}{2} - \tanh\frac{k\,l}{2}, \quad . \quad (13)^*$$

and those of the anti-symmetrical vibrations from

$$2\,Q = +\cot\frac{k\,l}{2} - \coth\frac{k\,l}{2}. \quad (14)$$

In these equations

$$2\,Q = \frac{2\,m}{M}(k\,l) - 2\,\frac{\lambda\,l^3}{I\,E}\,\frac{1}{(k\,l)^3} = \mu\,(k\,l) - \phi\,\frac{1}{(k\,l)^3}, \quad . \quad . \quad . \quad (22)$$

where μ is the "characteristic mass ratio" (CMR) and ϕ the "characteristic stiffness ratio" (CSR), two non-dimensional factors which determine the vibrational characteristics of the system. If consecutive roots of equation (13) and equation (14), respectively, are known as k_1, $k_2 \ldots k_i, \ldots$ the natural frequencies of the consecutive modes can be calculated by

$$f_i = \frac{k_i^2}{2\,\pi}\sqrt{\frac{I\,E}{A\,\rho}}. \quad . \quad . \quad (5)$$

To find the natural frequencies of the beam, we plot 2 Q as a function of $k\,l$ and also $-\tan\frac{k\,l}{2} - \tanh\frac{k\,l}{2}$ for the symmetrical modes and $\cot\frac{k\,l}{2} - \coth\frac{k\,l}{2}$ for the anti-symmetrical modes against $k\,l$. The intersection of the 2 Q curves with these gives the values for k_i.

In general, the lumped mass m of the supports is negligible compared with the mass of the beam and so we may take $\mu = 0$. The solution of the frequency equations for this case can be performed directly with Fig. 5. In the graph, 2 Q is plotted for a series of values of the CSR ϕ. These curves have two asymptotes, the negative part of the ordinate axis and the positive part of the abscissa. The abscissa forms the extreme case of $\phi = 0$ when $2Q = 0$, that is, theoretically, a beam free at both ends, or practically, negligible stiffness and mass of the supports. The $-\tan\frac{k\,l}{2} - \tanh\frac{k\,l}{2}$ curves (thick lines) and the $\cot\frac{k\,l}{2} - \coth\frac{k\,l}{2}$ curves (dotted lines) are asymptotic to integral multiples of π.

It can be seen from the graph that for $\phi = \infty$, that is, for infinitely stiff supports, the solution of the frequency equations will be integral multiples of π, as it should be, for this is the conventional "freely supported ends" case. The introduction of a small amount of flexibility of the supports has the effect that all roots (natural frequencies) are decreased, the decrease being the greater the higher the mode of vibration in question. For decreasing values of ϕ any root tends to a limit. If the mode under consideration is symmetrical it will tend towards the root of the nearest lower symmetrical mode belonging to the free-free case. Thus, the root of the fifth mode of the freely-supported beam (rigid supports) which is 5π tends towards the fourth root of the free-free beam (negligible stiffness of the supports) which is 10·996. The higher the root, the sooner it will reach, for all practical purposes, its lower limit.

For small values of ϕ the first two natural frequencies of the beam can be calculated with the assumption that an infinitely-rigid beam is resting upon two springs. In this case, the natural frequency of the symmetrical mode is

$$f_1 = \frac{1}{2\,\pi}\sqrt{\left(\frac{2\,\lambda}{2\,m + M}\right)}, \quad . \quad (20)$$

and the anti-symmetrical mode is

$$f_2 = \frac{1}{2\,\pi}\sqrt{\left(\frac{6\,\lambda}{6\,m + M}\right)}. \quad . \quad (21)$$

It can be seen from the graph that, owing to the fact that equation (19) of the Appendix is valid up to values of $\phi = 5·0$ for the symmetrical case and to $\phi = 25$ for the anti-symmetrical case, equation (20) and equation (21) give good approximations up to these limits. Thus, if the beam is supported by highly flexible supports, when vibrating in the fundamental mode it will vibrate without deformation.

In some cases, the mass of the supports cannot be neglected and the CMR $\mu = 0$. One of these cases occurs when the beam is supported by rigid end supports which are resting on an elastic foundation (experiment A). An exact solution of the last problem appears to be involved, but as an approximation an equivalent mass and spring constant can be determined experimentally. The effect of both μ and ϕ can be investigated with the aid of a graphical construction explained in Fig. 6, page 710. First, let us assume that $\phi = 0$ but $\mu \neq 0$, that is, we attach a mass to each end of a free-free beam or, practically speaking, to a beam which rests upon highly flexible supports. The 2Q curves for this case will be straight lines passing through the origin which have a slope of $\frac{2\,m}{M}$ (paying due regard to the different scales on the ordinate and abscissa axis). Increasing values of the CMR μ will decrease the roots of the free-free beam and they will tend to the nearest lower root belonging to the freely-supported beam which has the same kind of symmetry. Again, the effect upon the higher modes is greater than upon the lower.

In the most general case, 2Q is a function of both μ and ϕ. The 2Q (μ, ϕ) curves are obtained in the following way (Fig. 6): we select the straight line

* The numbers of equations relate to their order in the Appendix.

corresponding to the given CMR (say, $\mu = \frac{1}{2}$) and subtract from its ordinates the ordinates of the given CSR curve (say, $\phi = 10^2$), that is, in the graph AB = A'B'.

To show the effect of the flexibility of the supports upon the dynamic deflection curves, the amplitude distributions of a beam for the first three modes of vibration have been calculated and are presented in Fig. 7, opposite. For this purpose, it is convenient to use equations (16) and (17). Fig. 7 contains the root kl which corresponds to each dynamic deflection curve and the factor $\Delta^2 = \frac{k^2}{k^2_\infty}$, which shows the relative decrease of frequency due to the flexibility of the supports relative to the frequency of the freely-supported case of the same mode. Below $\phi = 0{\cdot}25$, the dynamic deflection curves do not differ appreciably from those of a free-free beam.

From experimentally-measured deflection curves of symmetrical modes, the CSR ϕ of a beam resting upon flexible supports can be determined by the following method. Let w_0 be the amplitude of vibration of the centre of the beam ($x' = 0$) and $w_{\frac{l}{2}}$ the amplitude of either end $\left(x' = \frac{l}{2}\right)$. If they point in the same direction, their signs are the same, but if they point in opposite directions, their signs are opposite. With the aid of equations (16) and (17) of the Appendix, we can calculate

$$\delta = \frac{w_0 - w_{\frac{l}{2}}}{w_0} = I - \frac{2\cos\frac{kl}{2}\cosh\frac{kl}{2}}{\cos\frac{kl}{2} + \cosh\frac{kl}{2}}.$$

The function $\delta(kl)$ is shown in Fig. 8. Having determined δ from the measured deflection curve, the corresponding value of kl will be found with the aid of Fig. 8. This value of kl is projected upon the line representing the function $-\tan\frac{kl}{2} - \tanh\frac{kl}{2}$ (thick line) in Fig. 5. The ϕ curve passing through the point of intersection will furnish the CSR of the beam and the supports.

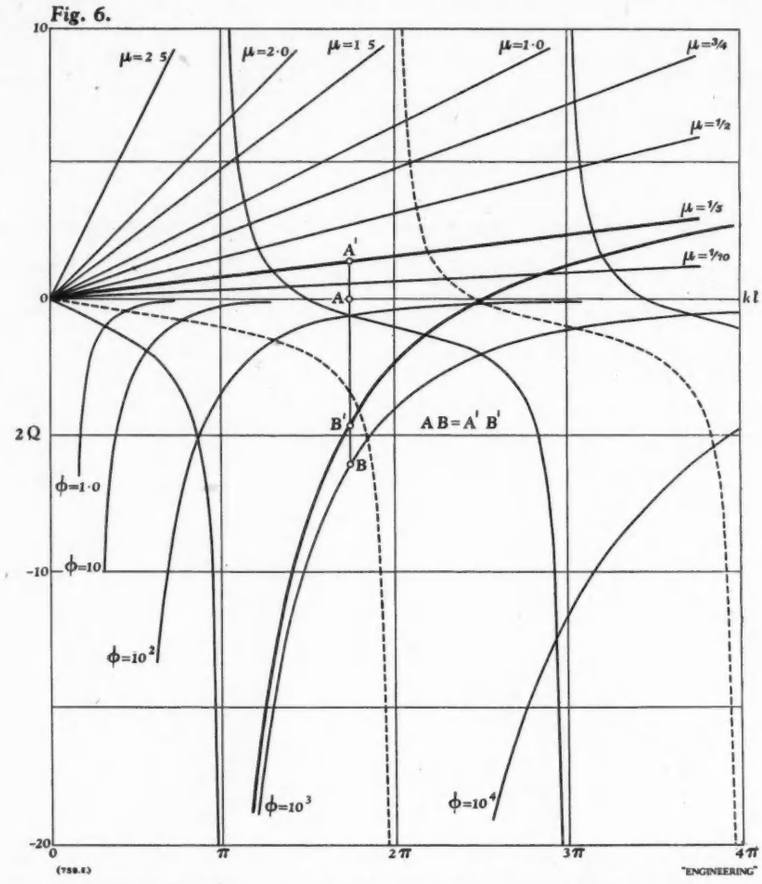
With this procedure the CSR of the base-plate, resting upon three steel blocks on the concrete floor and on the wood floor, has been determined. It was assumed that the CMR was negligible. From Fig. 2, experiment A, we find that on the concrete floor $\delta = 0{\cdot}661$ and from Fig. 4, experiment A, on the wood floor $\delta = 0{\cdot}676$. The corresponding values of kl are 2·80 and 2·88. From Fig. 5, we find that the CSR was approximately $\phi = 1{\cdot}75 \times 10^2$ for the concrete floor and $\phi = 2{\cdot}0 \times 10^2$ for the wood floor. If we had considered the CMR, slightly higher values would have been found. Thus, upon perfectly rigid supports the natural frequency of the plate would be about 2,800 r.p.m. In experiment F, the CSR value was in the region of $\phi = 0{\cdot}5$, which explains why, at the lowest resonance frequency, practically no deformation of the beam was observed. The natural frequency of the next symmetrical mode (third mode) was probably near to that of the second mode, the free-free plate, that is, about 6,250 r.p.m., which is well outside the range investigated. The dynamic deflection curves of this experiment were measured at 2,000 r.p.m. which is the region which, from the point of view of vibrations due to out-of-balance forces, is most interesting. The deflection curves show (curves F) how the third mode of vibration develops. It should be added that the reason for not observing any anti-symmetrical vibrations in the investigations was due to the fact that the exciting force was acting in the centre of the beam, i.e., the method of excitation was symmetrical.

By increasing the number of supports, the stiffness of the plate is increased which, in turn, must result in a higher natural f quency. Thus, it is not surprising that the natural frequencies in experiments B, E and G were higher than in the experiments with three-point mountings of the same materials. The dynamic deflection curves of the eight-point mountings show a similar deformation to that of the three-point mountings, but a much smaller bending. Eight felt pads appear to be an exception, for the deformation resembles that of three rubber pads F in Figs. 2 and 4.

The smallest amplitude and greatest damping occurred in the case of experiment C when the plate was lying directly upon the floor. The resonance frequency for the wood floor was higher than for the concrete floor. This was to be expected, for the analysis of the experimental results of the three-point mountings showed that the wood floor possessed a slightly higher CSR value, that is, slightly greater stiffness. In spite of these facts, this type of mounting is not altogether favourable. Large machines have usually a very low natural frequency which, in the case of a suitable mounting, may be below the frequency of any out-of-balance forces. By mounting the structure directly upon the floor, the value of the natural frequency may greatly increase and, if it corresponds with that of the out-of-balance forces, a completely unpredictable deformation of the structure may result. It is mainly the unpredictability of the vibrational characteristics which is objectionable. This is due to the fact that the floor is never completely flat and consequently the area of contact is not uniformly distributed. Moreover, the area of contact will vary if the machine is set up at another location. It may also vary in time, resulting in a slow deterioration of the original conditions. Owing to these reasons, this method of setting up the machine for testing purposes is not to be recommended.

VIBRATIONS OF MACHINE TOOL STRUCTURES.

Fig. 6.



The present investigation shows the importance of developing and testing machine-tool structures upon mountings and foundations similar to those on which they are intended to work. The kind of mounting which will give the best result depends upon the combined vibrational characteristics of the structure and its foundation. In the case of beam-like structures which are supported at the ends or near them, the method given permits the calculation of the natural frequencies and dynamic deflection curves. The vibrational characteristics of structures of this type can be varied within wide limits. In many cases, it is possible to avoid vibration due to out-of-balance forces by placing the structure on a support of greater or smaller stiffness. Most structures are supported not only at the ends but also at intermediate points and since there is no theoretical investigation available for this problem, it is difficult to arrive at definite conclusions. In general, it may be said that structures with a relatively high natural frequency (say about 4,000 r.p.m.) should be mounted directly upon the floor. Both rubber and felt mountings would decrease their natural frequency and might make them susceptible to out-of-balance forces. However, other considerations, such as the transmission of vibrations to and from other machines, may necessitate the use of vibration isolating and absorbing materials and precision balancing of rotating parts may be the only solution. Felt mountings are likely to give good results in the case of structures of a low or very high (say above 5,000 r.p.m.) natural frequency. Their effect is to decrease the natural frequency and thus bring it below the working range. Owing to the increased damping, little vibration will be transmitted.

Little is known about the behaviour of felt and rubber mountings under practical conditions when

VIBRATIONS OF MACHINE TOOL STRUCTURES.

Fig. 7.

ϕ	First Mode	Second Mode	Third Mode
∞	$kl=\pi$ $\Delta^2=1\cdot0$	$kl=2\pi$ $\Delta^2=1\cdot0$	$kl=3\pi$ $\Delta^2=1\cdot0$
5×10^3	$kl\cong3\cdot10$ $\Delta^2\cong0\cdot975$	$kl=6\cdot17$ $\Delta^2=0\cdot967$	$kl=9\cdot1$ $\Delta^2=0\cdot934$
10^3	$kl\cong3\cdot05$ $\Delta^2\cong0\cdot945$	$kl=5\cdot82$ $\Delta^2=0\cdot860$	$kl=7\cdot9$ $\Delta^2=0\cdot702$
5×10^2	$kl=3\cdot00$ $\Delta^2=0\cdot915$	$kl=5\cdot4$ $\Delta^2=0\cdot738$	$kl=7\cdot0$ $\Delta^2=0\cdot552$
10^2	$kl=2\cdot7$ $\Delta^2=0\cdot74$	$kl=4\cdot0$ $\Delta^2=0\cdot406$	$kl=5\cdot5$ $\Delta^2=0\cdot341$
0·25	$kl=0\cdot70$ $\Delta^2=0\cdot047$	$kl=0\cdot9$ $\Delta^2=0\cdot0205$	$kl\cong4\cdot7$ $\Delta^2=0\cdot247$

(758.F) "ENGINEERING"

Fig. 8.

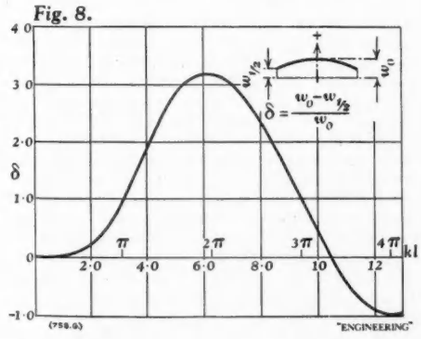


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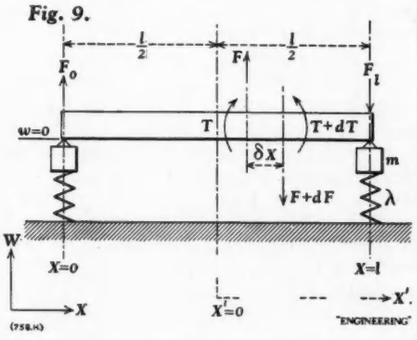
Fig. 9.



(758.H) "ENGINEERING"

they are used for relatively heavy structures. The damping capacity of felt is higher than that of rubber but its behaviour after prolonged service is unknown. The heat conductivity of rubber is small and since the absorbed energy is not dissipated, a considerable increase of temperature of the unit is inevitable. No published information appears to be available on the ageing effect of temperature upon mounting units.

The authors wish to express their thanks to Messrs. James Archdale and Company, Limited, Worcester, for permission to publish the experimental results and to Professor R. N. Arnold, University of Edinburgh, for the interest he took in the investigation.

APPENDIX.

The Vibration of a Freely-Supported Beam Resting Upon Elastic Supports.—The vibrations of a beam with freely-supported ends are treated in textbooks with the assumption that the supports are perfectly rigid. In small-scale experiments this assumption can be approximated to, but in the case of large-scale tests the flexibility of the supports has to be taken into consideration. Thus the present problem is interesting not only in cases where flexible supports are deliberately introduced with the aim of isolating vibrations, but also where they have to be accepted as an inevitable experimental fact. The solution given is of a more general nature than that normally presented for the vibration of a beam with "free-free end conditions" and with "freely supported ends" can be regarded as a special case of it.

We shall assume that a uniform elastic beam of length l is resting upon two elastic end supports which can be represented by an equivalent mass-spring system consisting of a mass m which is connected to the perfectly rigid foundation by a spring of stiffness λ (Fig. 9). Furthermore, we assume that these supports do not constrain any angular displacements of the end of the beam.

The equation of motion of the free vibrations of the beam, neglecting rotary inertia and damping, can be written:—

$$\alpha^2\frac{\partial^4 w}{\partial x^4}+\frac{\partial^2 w}{\partial t^2}=0, \qquad . \quad (1)$$

where $\alpha^2=\frac{E\,I}{A\,\rho}$, and w = the vertical displacement of the beam, A = the area of the beam cross-section, ρ = the density of the beam material, and I E = the flexural rigidity of the beam.

Let us assume that, if the beam vibrates in one of its normal modes of vibration, the solution of equation (1) is of the type

$$w=X\,(a\cos pt+b\sin pt), \qquad . \quad (2)$$

where X is a function of the co-ordinate x only, which determines the shape of the normal mode under consideration; a and b are two constants, the values of which are determined by the initial conditions of the motion. Substituting equation (2) in equation (1), we get

$$\frac{\partial^4 X}{\partial x^4}=\frac{p^2}{\alpha^2}X. \qquad . \quad . \quad (3)$$

We shall solve this equation with a function of the type

$$X=C_1\cosh kx+C_2\sinh kx+C_3\cos kx+C_4\sin kx, \qquad . \quad . \quad . \quad (4)$$

in which $C_1 \ldots C_4$ are constants which are determined by the end conditions of the beam; k determines the natural frequency by

$$=\frac{p}{2\pi}=\frac{\alpha\,k^2}{2\pi}=\frac{k^2}{2\pi}\sqrt{\frac{E\,I}{A\,\rho}}. \qquad . \quad (5)$$

The end conditions are arrived at by considering the interaction between the supports and the beam at $x=0$ and at $x=l$. The motion of the concentrated mass m of the supports can be regarded as a forced vibration, the exciting force being a force

equal to but opposed to the shearing force acting on the beam. Denoting the shearing force by

$$F = I E \frac{\partial^3 w}{\partial x^3},$$

the force F_0 acting at the origin $x = 0$ will point in the $+w$ direction, while, at $x = l$, the acting force F_l will point in the $-w$ direction. Thus, the end conditions are furnished, at at $x = 0$ by,

$$m \frac{\partial^2 w_0}{\partial t^2} + \lambda w_0 = - I E \left(\frac{\partial^3 w}{\partial x^3}\right)_{x=0}, \quad (6)$$

and at $x = l$, by

$$m \frac{\partial^2 w_l}{\partial t^2} + \lambda w_l = + I E \left(\frac{\partial^3 w}{\partial x^3}\right)_{x=l}, \quad . \quad (7)$$

where w_0 and w_l are the amplitudes of vibration of the beam at $x = 0$ and at $x = l$, respectively.

The other two end conditions are furnished by the assumption that the supports do not exert any restraining effect upon the angular displacements of the ends of the beam, that is, the moments acting on the beam at $x = 0$ and at $x = l$ are zero.

$$T = I E \left(\frac{\partial^2 w}{\partial x^2}\right)_{\substack{x=0 \\ x=l}} = 0. \quad . \quad (8)$$

Substituting equation (4) in equation (6),equation (7) and equation (8) and putting $x = 0$ and $x = l$, we obtain the following set of equations for k and the constants $C_1 \ldots C_4$

$$\left.\begin{aligned} &C_1 - C_3 = 0, \\ &C_1 \cosh kl + C_2 \sinh kl - C_3 \cos kl - C_4 \sin kl = 0. \\ &C_1 Q - C_2 + C_3 Q + C_4 = 0, \\ &C_1 (Q \cosh kl + \sinh kl) + C_2 (Q \sinh kl + \cosh kl) \\ &+ C_3 (Q \cos kl + \sin kl) + C_4 (Q \sin kl - \cos kl) = 0. \end{aligned}\right\} \quad . \quad . \quad . \quad (9)$$

where the following abbreviation is used

$$Q = \frac{m p^2 - \lambda}{E I k^3}. \quad . \quad . \quad (10)$$

Equation (9) represents a set of linear homogeneous equations which have a solution only if their determinant is equal to zero. The evaluation of this determinant leads to the frequency equation of the system

$$2 Q^2 \sin kl \sinh kl + 2 Q (\sin kl \cosh kl - \cos kl \sinh kl) + 1 - \cos kl \cosh kl = 0. \quad . \quad . \quad (11)$$

This, being a quadratic equation in Q, has the following solutions:

$$2 Q = \cot kl - \coth kl \pm (\operatorname{cosec} kl - \operatorname{cosech} kl) \quad . \quad . \quad . \quad (12)$$

The plus sign gives those frequencies which correspond to the symmetrical vibrations, that is, when the amplitudes of the ends are in phase. For this case, equation (12) can be written

$$2 Q = - \tan \frac{kl}{2} - \tanh \frac{kl}{2}. \quad . \quad (13)$$

The minus sign gives the frequencies of the anti-symmetrical vibrations, that is, when the ends move in opposite phase. The frequency equation has the form

$$2 Q = \cot \frac{kl}{2} - \coth \frac{kl}{2}. \quad . \quad (14)$$

The last two statements can be shown in the following way: equation (9) determines not only the natural frequency of each mode of vibration but also the amplitude distribution along the beam, that is, the dynamic deflection curves. Let us assume that Q and kl are values which satisfy the frequency equation. We can express the constants, C_2, C_3, C_4, in terms of C_1 from equation (9). These are substituted in equation (4), which, in turn, is substituted in equation (2). We obtain as the expression for the amplitudes

$$\begin{aligned} w = C_1 \{ &[(\cos kl - \cosh kl) \\ &- Q (\sin kl + \sinh kl)] (\cosh kx + \cos kx) \\ &+ [Q (3 \cos kl + \cosh kl) \\ &+ (1 - 2 Q^2) \sin kl + \sinh kl] \sinh kx \\ &+ [Q (3 \cosh kl + \cos kl) + (1 + 2 Q^2) \sinh kl \\ &+ \sin kl] \sin kx \} (a \cos pt + b \sin pt), \end{aligned} \quad (15)$$

where a and b are constants which are determined by the initial conditions. If we transfer the origin of the co-ordinate system to the centre of the beam by replacing x by $x' = x - \frac{l}{2}$ and substitute the value of Q from equation (13) and equation (14) respectively in the resulting equation, we obtain the following two equations:

With equation (13),

$$w = D (\cos \frac{kl}{2} \cosh kx' + \cosh \frac{kl}{2} \cos kx') (a \cos pt + b \sin pt), \quad (16)$$

and with equation (14),

$$w = D^1 (\sin \frac{kl}{2} \sinh kx' + \sinh \frac{kl}{2} \sin kx') (a \cos pt + b \sin pt), \quad (17)$$

It can be seen that equation (16) represents the symmetrical amplitude distribution since

$$\cos kx' = \cos (-kx')$$

and

$$\cosh kx' = \cosh (-kx').$$

For similar reasons it is obvious that equation (17) gives the anti-symmetrical modes of vibration.

It has already been mentioned that the vibrations of a beam with free-free ends and that of a freely-supported beam can be regarded as special cases of the present solution.

Free-Free Beam.—If the mass and the spring constant of the supports are equal to zero or very small, $m = 0$ and $\lambda = 0$, we find that $Q = 0$ and the frequency equation (equation (11)) takes the form $\cos kl \cosh kl = 1$, which is the frequency equation of the free-free beam. The first four consecutive roots of this equation are

$k_1 l$	$k_2 l$	$k_3 l$	$k_4 l$.
0	4·730	7·853	10·996

The expression for the amplitudes is obtained from equation (15) by making $Q = 0$.

Freely-Supported Beam.—By making the stiffness of the supports infinite $\lambda = \infty$, we find $Q = \infty$. Dividing equation (11) by Q^2 and making $Q \to \infty$, we obtain $\sin kl \sinh kl = 0$, which is the frequency equation of the freely-supported beam. The first four roots are

$k_1 l$	$k_2 l$	$k_3 l$	$k_4 l$.
π	2π	3π	4π

The expression of the amplitudes is obtained by dividing equation (15) by Q^2 and making $Q \to \infty$.

Rigid Beam Resting Upon Flexible End Supports.—If $E \to \infty$ and consequently Q and $k \to 0$ in such a way that

$$\frac{Q}{k} = \frac{m p^2 - \lambda}{k^4 E I} = \frac{m p^2 - \lambda}{A \rho p^2}, \quad . \quad (18)$$

remains finite, we can write equation (11) in the following way:

$$\frac{2 Q^2}{k^2} \sin kl \sinh kl + \frac{2 Q}{k^2} (\cosh kl \sin kl - \cos kl \sinh kl) + \frac{1 - \cos kl \cosh kl}{k^2} = 0.$$

Since k and kl will be small, we can replace the sin, cos, sinh and cosh terms by the first few terms of their expansions. Let us expand up to the fourth power of kl and, after rearranging, we are left with the following quadratic equation in $\frac{Q}{k}$

$$(kl)^2 \left[\left(\frac{Q}{k}\right)^2 + \frac{Q}{k} \frac{2 l}{3} + \frac{l^2}{12}\right] = 0.$$

The solution of this equation is

$$\frac{Q}{k} = -\frac{l}{2} \quad \text{or} \quad \frac{Q}{k} = -\frac{l}{6}, \quad . \quad (19)$$

that is, from equation (18),

$$\frac{m p^2 - \lambda}{A \rho p^2} = -\frac{l}{2} \quad \text{or} \quad -\frac{l}{6},$$

and so the frequency of the symmetrical mode will be

$$f_s = \frac{p_s}{2\pi} = \frac{1}{2\pi} \sqrt{\left(\frac{2\lambda}{2m + M}\right)}, \quad (20)$$

and of the anti-symmetrical mode

$$f_{as} = \frac{p_{as}}{2\pi} = \frac{1}{2\pi} \sqrt{\left(\frac{6\lambda}{6m + M}\right)}, \quad (21)$$

as it should be.

To find the solutions of the frequency equations we plot 2Q as a function of kl and also $-\tan \frac{kl}{2}$ $-\tanh \frac{kl}{2}$ for the symmetrical modes and $\cot \frac{kl}{2}$ $-\coth \frac{kl}{2}$ for the anti-symmetrical modes against kl and determine the intersections of these two sets of curves. The detailed description of this procedure can be found in the main text.

IMPROVED VENTILATION OF LONDON TUBE RAILWAYS.

WHEN the City and South London Tube Railway was opened in 1890 it was considered that the movements of the trains would provide sufficient ventilation of the underground stations. This was soon found to be fallacious, and in 1903 a large fan with an output of 100,000 cub. ft. per minute was installed at the Wood Lane mouth of the Central London Railway three years after that line's inauguration. This fan was mainly run at night and could, it was claimed, displace the entire air of the line from Shepherd's Bush to the Bank in an hour.

The same practice was adopted when the Bakerloo, Piccadilly and Hampstead Tubes were opened in 1906-07, with the difference that fans with outputs of 20,000 cub. ft. per minute were installed at most of the stations. In 1911, the majority of the Central London stations were also equipped with fans which were designed to deliver 6,000 cub. ft. of ozonised air per minute, thus giving rise to the smell which has characterised tube stations for several decades. At present, 98 fans displacing a total of 4·5 million cub. ft. of air per minute are at work, most of which are of the extraction type whereby the vitiated air is exhausted to the outside atmosphere and a corresponding volume of fresh air is drawn in through the station premises. As a result, passengers enter with it and so become gradually accustomed to the change in atmospheric conditions. Nevertheless there may be some cold draughts on first entering unless relief shafts have been provided. Large-diameter relief shafts have therefore been sunk between the open air and the tunnels to reduce the velocity of the draughts on the platforms and in the subways and tunnels.

The main ventilating problem, which has increased in importance during the past 30 years, is, however, that heat is stored in the clay surrounding the tunnels. Since 1920, in fact, it has become apparent that tube temperatures have been steadily rising owing to this cause and to the more intensive train services. In 1949 the average annual temperature on all tube lines was 73 deg. F.; the average on the Northern line from Kennington southward was 76·5 deg. with particularly hot spots at Kennington (77 deg.), Balham (78 deg.) and Oval (78 deg.). To improve these conditions two additional fans of a powerful modern type are being installed at Kennington Park and Balham substations, while shafts have been sunk near the Oval and Balham passenger stations to relieve the draught. The result with one of the new fans at work is a noticeable improvement in overall ventilation and a reduction of the draughts by one half.

DESIGN AND RESEARCH BUILDING.

FIG. 1. EXTERIOR OF BUILDING AT NIGHT.

FIG. 2. SIR CHARLES PARSONS MEMORIAL HALL.

DESIGN AND RESEARCH BUILDING OF C. A. PARSONS AND COMPANY.

IT has for many years been evident that more accommodation would be necessary to house the research, technical, administrative and accounting staffs at the Heaton works of Messrs. C. A. Parsons and Company, Limited. Provision of such accommodation had, however, to be postponed until the existing factories had been modernised, and the construction of new and more spacious shops had been completed. It was not therefore until 1950 that final preparations could be made for the construction of the well-designed building described in this article. The new building, the striking appearance of which at night is illustrated in Fig. 1, has been erected on a site which was originally partly occupied by a machine shop built in 1889, when Sir Charles Parsons established the Heaton Works.

FOUNDATIONS AND STRUCTURE

As regards construction, investigations showed the existence of large deposits of soft loamy clay extending to a depth of about 35 ft., in addition to first-class load-bearing clay near the surface. Bores were therefore made until solid rock was encountered, and *in situ* reinforced-concrete piles were then poured. These piles, which number 400, are installed in groups below the foundation of each stanchion, their diameter varying from 15 in. to 19 in. and their lengths from 10 ft. to 40 ft. As water under high pressure was encountered at rock depths, continuous pumping was necessary and dummy bore holes have been left below the basement to carry off the flow, which is then collected in a drainage system immediately below floor level. The pressure on the walls is thus relieved.

Reinforced-concrete pile caps, which form the bases of the stanchions and in some cases carry a load of 475 tons, are placed below the basement or ground floors and are connected by reinforced concrete beams, which were also constructed *in situ*. The basement itself is a heavily reinforced concrete tank, the interior surfaces and the floor of which are covered with a layer of asphalt 1 in. thick. Inside this tanking is a second reinforced concrete floor and 9-in. brick walls. The superstructure consists of a steel frame cased in reinforced concrete and in the Shields-road wing the columns are arranged so that all the rooms are free from obstruction. Owing to the climatic conditions, the exposed surfaces are, where possible, of hard impervious material such as pre-cast terrazo, polished granite and pressed facing bricks which can be readily washed down.

The external glazing consists of double units made up of two panes of polished plate glass separated by a metal spacer. The space thus formed is hermitically sealed and contains dehydrated air, thus improving both the thermal and sound insulation. Most of the glass rests on rubber blocks, which are bedded in non-setting mastic and are held in the reveals by snap-on anodised aluminium beading. The consequent absence of sashes and the use of anodised aluminium will eliminate the need for external painting.

The structural floors throughout the building consist of reinforced-concrete troughs, 70 per cent. of which were laid *in situ* on sheet-steel formers, while the remainder were precast. These troughs are overlaid with 2¼ in. of fine aggregate concrete and 1 in. of sand and cement screed to receive either 12-in. square cork tiles in most of the accommodation or acid-resisting composition tiles in the laboratories. In certain places, such as machine rooms and laboratories, both the supporting steelwork and the surfaced concrete forming the floors were strengthened.

The contractors for the building work were Stephen Easten, Limited, Westgate-road, Newcastle-upon-Tyne, the steelwork being supplied by Alexander Findlay and Company, Limited, Motherwell.

LAYOUT AND ACCOMMODATION.

In plan the building is in the form of an "L," one leg of which is 311 ft. long and faces west along Depot-road. The other main frontage is 183 ft. long and is set back 40 ft. from the Shields-road building line, the intervening space being used as a drive and car park, and being spanned by a canopy to provide shelter. The main entrance hall opens into an annexe, which is used for reception purposes and is illustrated in Fig. 2. It is of interest in that it contains a number of specimens and models of Sir Charles Parsons' original work, as well as a sculptured plaque of this famous engineer by Sir William Reid Dick and a portrait by Sir William Orpen. A corridor leads from the hall to the ground floors of the two wings, that on the north side also giving access to the works. On the ground floor of the Shields-road wing the works management group, the works engineers and the buying and planning departments are accommodated, while that of the Depot-road wing contains the electrical, mechanical and material research laboratories. The first floors in both wings are given up to research and development and here are to be found the physics, applied mechanics, chemical and metallurgical laboratories, as well as the gas-turbine research offices and a library.

The second floor in the Depot-road wing is entirely occupied by the mechanical drawing office, and that in the Shields-road wing by the mechanical design and technical sales departments. The mechanical drawing office, of which a view is given in Fig. 3, is no less than 216 ft. long by 62 ft. wide by 12 ft. 6 in. high and accommodates 216 draughtsmen, so that the floor area per person is 62 sq. ft., including gangways. One of the combined desk and drawing-board units is shown in Fig. 5. The third floor of the Depot-road wing houses the tracing offices and the accounts division, while that in the Shields-road wing contains board rooms, conference rooms and the offices of the directors and senior members of the staff. The mezzanine floor which has been incorporated in the Shields-road wing by varying the heights of the rooms is occupied by the accountants, publicity and construction departments. The fourth and fifth floors of the Depot-road wing are devoted to the alternator and

transformer designers, with associated drawing offices, while those in the Shields-road wing accommodate luncheon rooms and kitchens. In general, the floors are completely open and obtain adequate natural lighting through windows which reach from sill to ceiling on both sides, the number of internal corridors being reduced to a minimum.

LIGHTING AND ELECTRICITY.

In the construction of such a building as this, consideration had naturally to be given at an early stage to such questions as artificial lighting, heating and ventilation. It was decided that the illumination must be sufficient to obviate the use of individual portable desk and drawing-board lamps and to provide an intensity of not less than 60 lumens per square foot over large areas of floor. It was also decided to employ a scheme which would remove any impression of low ceiling height, such as might have been given by the effect of perspective if ordinary pendants had been used. The result, which is clearly shown in Fig. 3, has been achieved by installing some 7,000 intermediate cold-cathode tubes, the aggregate length of which is about 12 miles. These tubes, as shown in Fig. 4, are housed in rows of reflectors running at right angles to the normal direction of view from the desks and facing the under surface of the ceiling in such a way that they are themselves concealed.

The reflectors consist of 9-ft. lengths of anodised aluminium troughing, which is perforated to prevent echoes, while sound is absorbed in superimposed scrap wool blankets. These reflectors are clipped to rectangular pipes and assist the heating of the building, as described below, while optically they are designed so that they throw no harsh shadows at their longitudinal junctions. Plastic strips have also been mounted along the joints between them to soften the effect further. The ceiling at the ends of and between the illuminated panels is formed of acoustic tiles, the different sections being interrupted at intervals by lay lights, above which tubes are placed to lighten the effect. The tubes are operated in groups of four from a transformer which is concealed above the tiles. Control is normally effected photo-electrically, the arrangement being such that the tubes in the central areas are first switched on automatically and then those near the windows. Manual control of the lamps in the central and outside blocks of lights on each floor is also available.

The entrance hall and museum are also lighted by cold-cathode tubes, installed above lay lights. The same system has also been used in the corridors, while the staircases are illuminated by simple lines of tubes installed behind glazed panels on the landings. The exterior of the building is lighted by 85-watt sodium floodlights which are installed on the top balcony, and by three 400-watt mercury units in the forecourt. The lighting scheme was prepared by the departments of C. A. Parsons and Company responsible for the architectural design of the building, the equipment being supplied by the General Electric Company, Limited.

Electricity is supplied from the mains through two transformers which, with the principal low-voltage circuit-breakers, are situated in a switch room at the north end of the basement. From this point cables are run in brickwork shafts to three distribution boards on each floor and thence in sheet-steel trunking under the floors to conduits embedded in the structural columns. These conduits are connected to the lighting transformers which, as already mentioned, are installed in the ceilings or behind removable wall panels. They are also connected to the power points which are provided in all the rooms so that portable equipment can be used. Power supplies to the machine rooms and laboratories are through separate circuits.

HEATING, VENTILATION AND ACOUSTICS.

The building is heated on a low-pressure system installed by G. N. Haden and Sons, Limited, 19, Woburn-place, London, W.C.1, hot water being circulated by calorifiers and ancillary equipment, which are installed in the Depot-road wing basement. These calorifiers are heated by steam from the works boilers, and are connected to flow and return pipes which are run in five brickwork shafts. The pipes supply three systems of ceiling heating;

DESIGN AND RESEARCH BUILDING.

FIG. 3. MECHANICAL DRAWING OFFICE.

FIG. 4. ILLUMINATED CEILING.

the first, installed throughout the greater part of the building, consists of continuous fabricated grids of 1 in. square steel pipes laid at 16 in. centres, which are fixed above the ceiling level at each floor and run laterally across the building. The rows of perforated anodised aluminium troughing, which form the lighting reflectors, also act as low-temperature radiant heating panels, and are fixed to the underside of these pipes by spring clips. Immediately above the grids are mats of slag wool in crepe paper coverings, so as to prevent loss of heat in the space between the pipes and the floor above. The perforations in the aluminium troughs of the lighting system provide acoustic insulation for the ceilings, as already mentioned, while flat perforated board, backed with Fibreglass mattresses, is used for the same purpose below the main structural floor beams and in the centre of the rooms.

In the halls, corridors and luncheon rooms perforated anodised aluminium sheets, 24 in. square, are fixed to the grids of square piping and are covered with acoustic blankets. In the kitchens, lavatories and stairways hot-water pipes embedded in the ceiling or plaster work are used. The heating system generally is divided into four zones, with independent thermostatic control, so as to compensate for the difference in temperature between the Shields-road wing, which faces north, and the Depot-road wing, which faces west.

Ventilation is effected by two 72-in. diameter fans, one of which supplies 75 per cent. of the air required on each floor of the Depot-road wing, and the other the remaining 25 per cent., as well as the whole of the Shields-road wing. This arrangement allows for a maximum of three changes of air per hour, which can be reduced in the winter to one and a half times by varying the speed of the fans, and in summer by opening the windows. Dampers are provided to allow a reduced quantity of air to be circulated should either fan be closed down.

DESIGN AND RESEARCH BUILDING.

FIG. 5. DRAWING OFFICE DESK UNIT.

The fans are installed in a chamber on the roof, one wall of which consists entirely of plate-glass louvres. Air is drawn in through these and passed through electrostatic filters and over heaters before reaching the fans. It is then distributed through galvanised sheet-steel trunking to branch ducts, which are laid in the space between the thermal blanket and the floor above. It is finally discharged into the rooms through anemostats.

Air is extracted at the rate of two and a half changes per hour, so that the building is under pressure when the windows are closed. In the Shields-road wing this extraction takes place through the space between the room and corridor ceilings, the air being discharged through dampers into the service shaft and withdrawn by a fan. In the Depot-road wing, grilles are fitted in continuous lines in the false wall panelling below the window sills on each floor, the space behind which forms a sealed extract duct. The air is drawn from this space into the ceiling, which thus forms an extract duct, and is thence exhausted by fans through damper-controlled openings into the shafts. Both the ventilating and heating systems are controlled from the calorifier room in the basement.

INTERNAL COMMUNICATIONS.

A great deal of thought was given at an early stage to the problem of traffic circulation in the building, owing to the fact that the starting and finishing times and lunch time occurred simultaneously for some 1,100 occupants. During the day, moreover, there is considerable movement between floors, and emergencies due to fire or lift breakdown had also to be taken into account. In addition to the main double stairway from the ground to the fifth floor, which is situated in the central hall and is 23 ft. wide, there are single stairways from the basement to the top floors at the extreme north and east ends of the building. The lift installation consists of one ten-person passenger lift and three continuously-running paternosters in the main hall; a 15-person passenger lift at the north end of the Depot-road wing; and a 20-cwt. goods and passenger lift at the east end of the Shields-road wing. All the passenger lifts are fitted with fully-automatic control, with photo-electrically operated equipment for opening the doors, and run at speeds of either 300 or 200 ft. per minute. They were installed by J. and E. Hall, Limited, Dartford, Kent.

The paternoster lifts, which were also installed by Messrs. Hall, are believed to be only the third of their kind to be installed in this country. Each consists of 14 open-fronted cars, which can accommodate two persons at a time, and run in a brick shaft which is separated by timber guides into up and down passages. The cars are suspended at diagonally opposite corners on two endless chains, which are driven from the plant chamber at a speed of about 80 ft. per minute. Horizontal transfer from the up to the down direction and vice versa takes place at the top and bottom of the shaft.

Both Post Office and internal telephone systems are installed. The switchboard is situated on the mezzanine floor in the Shields-road wing and consists of five panels arranged in an arc so that the handling of calls is facilitated. The internal telephone exchange is situated in the basement and is entirely automatic. It comprises three 100-line units which at present supply 200 lines and allow 30 calls to take place simultaneously.

In conclusion, it may be mentioned that the demolition of the previous buildings on the site was begun on April 1, 1951, and was completed in four weeks. Excavation was started on May 2 and piling was undertaken from late June until October, often under extremely difficult conditions owing to the bad weather. The erection of the steelwork could not be started until October, due to delays in delivery. Nevertheless, in spite of severe weather again, it was completed by the end of January, 1952. Building continued during the summer of that year, the second floor of the Depot-road wing being handed over to the mechanical drawing office on October 22, and the third floor in the same wing four weeks later. The building was fully occupied in November, 1952. The cubic content of the new building is 2,600,000 cub. ft., and the total floor area about 185,000 sq. ft. The weight of the structural steelwork is 1,010 tons and 900,000 bricks were used. The lighting installation required 21 miles of wire, and 25 miles of 1-in. square pipe were necessary for the heating system.

THE AYCLIFFE PLANT OF BAKELITE, LIMITED.

THE main factory of Messrs. Bakelite, Limited, pioneer makers of plastic products, is situated at Tyseley, Birmingham, but during the second world war, like many other firms, they established various plants in different parts of the country. In one of these, at Feniscowles, near Blackburn, they commenced in 1943 to manufacture vinyl resin compounds for covering electric cables; previously, their interests had lain in the field of phenolic and urea thermosetting products. At the end of the war, they closed their several dispersal plants and again concentrated their production at Tyseley; but it was not possible to expand the facilities there sufficiently to accommodate all the equipment from the other works and therefore, by arrangement with the Board of Trade, a site was acquired at Aycliffe, Co. Durham, for the manufacture of thermoplastic products.

The site selected, of some 35 acres, included a number of buildings which had formed a Royal Ordnance Factory. Some of these were used to house the vinyl-compounding equipment from Feniscowles, and others were converted for use as offices, laboratories, stores and engineering shops for maintenance purposes. This portion of the works went into production in 1948, but it was still insufficient and new buildings were constructed for the manufacture of phenolic moulding materials, plant for the production of urea materials, and equipment for compounding, calendaring and press-polishing sheets of polyvinyl-chloride (P.V.C.). This has now been supplemented by the erection of the new resin plant illustrated in Figs. 1 to 3, page 716, which has recently commenced production. It occupies part of a 47-acre site immediately adjoining the original 35 acres and comprises low-temperature storage and mixing tanks for monomers; polymerising equipment; drying, grinding and screening plant; and facilities for weighing and storing the final products, polyvinyl and copolymer resins. It is being used at present to produce the vinyl chloride-acetate copolymer known as Vybak VYNW, a general-purpose resin which has been developed to afford easier working, fluxing and plasticising than the "straight" P.V.C. resins, while retaining their mechanical and electrical properties. The output is stated to be at the rate of several thousands of tons per annum, which is enough to provide a surplus for sale to other compounding firms after meeting the Bakelite Company's own requirements.

Fig. 1 is a general view of the new building and its associated equipment, showing in the foreground the refrigeration and gas-storage units, which are finished with aluminium paint over the insulation. Fig. 2 is a view from the south-west end and gives a better impression of the main building, in front of which are the storage and weighing bins. Fig. 3 shows the refrigerating plant, with the Worthington-Simpson ammonia compressors. The refrigerating medium is calcium-chloride brine. Other services provided are for the supply of circulating water, mainly for the refrigerating equipment; nitrogen, which is required as a inert blanket in all equipment where vinyl chloride is either stored or polymerised, and to protect the instruments from being blocked by the polymer, which would occur if the monomer were not excluded; and for fire-extinction. The whole of the machines are normally driven by electric motors, but there is also a steam stand-by plant, and a Diesel-driven generator which comes into service automatically in the event of failure of the mains current.

The raw materials are brought in by road in tank vehicles, from which they are transferred to the storage tanks either by pumps or by gas pressure. Thence they are pumped to weighing tanks in the proportions necessary for the type of resin being made, and from the tanks to the polymerisation system; this is designed to enable resins to be made according to any of the usual techniques, and is sufficiently flexible to cover a wide range of copolymer products. This portion of the plant is out of doors and can be seen in part in the illustrations. The final drying, grinding and screening of the resin, and the subsequent blending and packing, are carried on inside the building. The processes are

THE VINYL RESIN PLANT OF BAKELITE, LIMITED, AT AYCLIFFE.

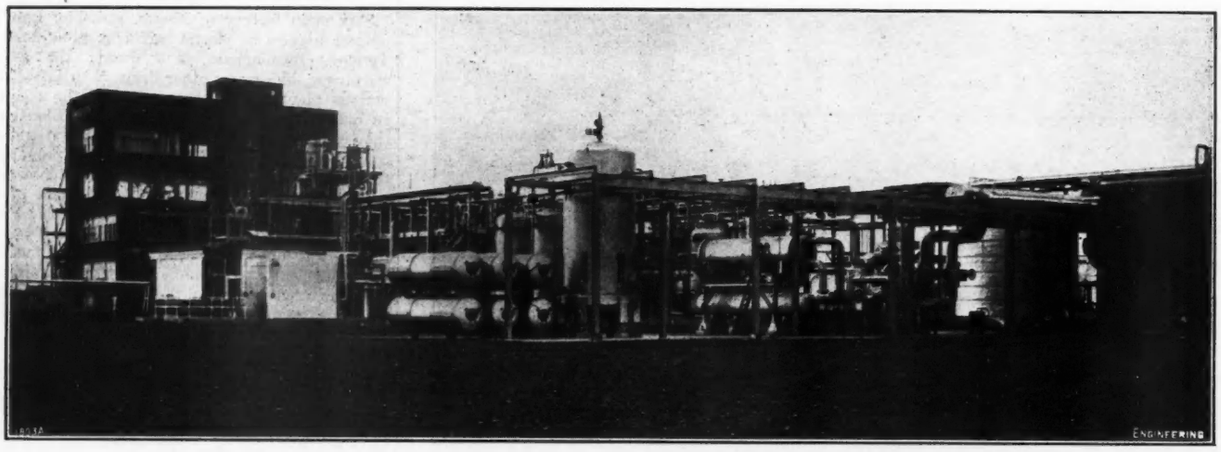


FIG. 1. GENERAL VIEW SHOWING OUTSIDE REFRIGERATION AND GAS-STORAGE EQUIPMENT.

regulated at all stages by servo-control equipment, so that the staff required to operate the plant is comparatively small. There is also a qualified inspection staff to test the incoming raw materials, and also the products at various stages of manufacture. The production processes are continuous, 24 hours a day through a seven-day week, and the inspection service, therefore, is also organised on a continuous basis. To ensure that the finished resin is uniform in all its characteristics, it is tested not only for its physical and chemical properties, but also in a variety of compounds, designed to show up any deficiencies.

The resins produced are either converted in the same works into moulding or extrusion compounds or into sheet, or are supplied to customers who do their own conversion. The initial compounding process is the same for moulding and sheet materials, the ingredients passing in turn through ribbon-type pre-blenders, Banbury mixers, and two roll mills. For moulding and extrusion compounds, strips of the materials are fed into granulators, where they are cut into chips of appropriate size for different applications. For the production of sheet, the compounds, after passing through the Banbury mixers and the mills, are fed to calendars which deliver sheets up to 54 in. wide and 0·030 in. thick. The calendared sheet is then either supplied to customers in rolls for further processing, such as embossing, or is press-polished on the premises. It will be seen, therefore, that the products of the Aycliffe works cover a wide range, from the completely rigid to soft rubbery textures; moreover, they can be supplied in practically any colour. The rigid grades have the advantage of exceptional dimensional stability, in addition to the characteristic properties of good chemical and electrical resistance, and they can be welded with great facility by the use of a hot-air torch. For the investigation of new developments and applications, there are well-equipped research laboratories at Aycliffe, though fundamental research is still carried out, as hitherto, in the company's main research department at Tyseley.

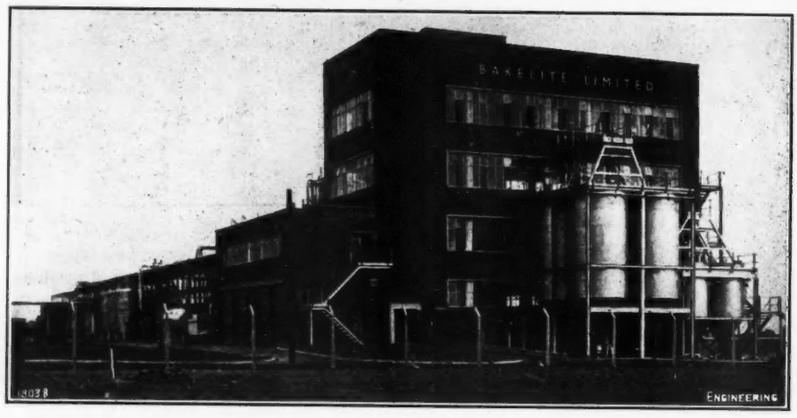


FIG. 2. STORAGE AND WEIGHING BINS.

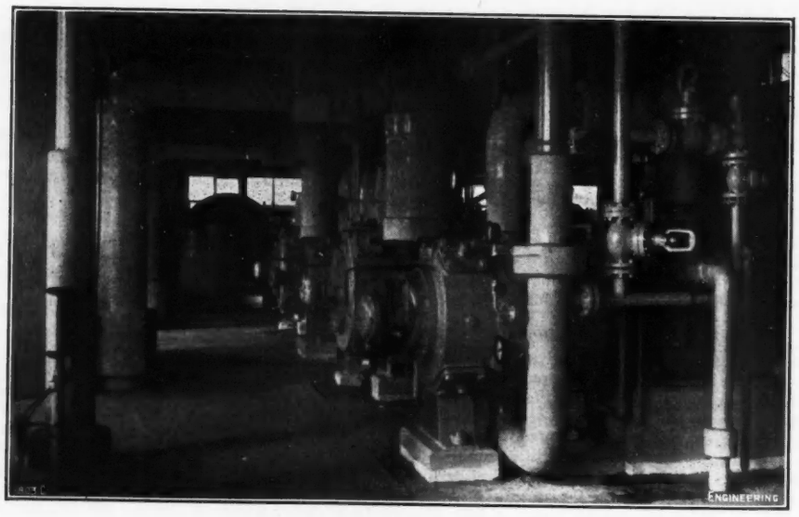


FIG. 3. REFRIGERATION PLANT.

SILICONE RUBBER IN INDUSTRY.—An exhibition which is intended to illustrate the basic properties of silicone rubber and to indicate how the material is being used in diverse fields of industry is being held at the head office of Midland Silicones, Ltd., 19, Upper Brook-street, London, W.1. It is open daily, from 10 a.m. to 6 p.m., until December 10. On Saturday, December 5, the hours are from 10 a.m. to 1 p.m. Numerous applications of Silastomer, the name given to the silicone produced by Midland Silicones, Ltd., are exhibited. Specimens supplied by a number of firms show the many forms in which the material is applied in the aircraft, engineering, electrical and other industries. Working models demonstrate how the material retains its rubber-like properties at temperatures from — 100 deg. F. to + 500 deg. F. Of particular interest is some extruded Silastomer tubing, having a bore of $\frac{1}{2}$ mm. and a wall thickness of 0·002 in., supplied by H. D. Symons & Co., Ltd.

FLEXIBLE COUPLINGS AT A REFINERY.—On a recent visit to the Fawley refinery of the Esso Petroleum Co., inspection was made of the "Metastream" flexible couplings for shafts, made by Metaducts, Ltd., Catherine Wheel House, High-street, Brentford, Middlesex. These couplings, described in ENGINEERING, vol. 173, page 578 (1952), are designed to have the minimum resistance to axial movement of the shafts, so that both motor and pump rotors may run in their natural positions without interaction. The couplings on the pumps dealing with the sludge from the catalytic cracking plant had been inspected after a year's service and were found to be in perfect condition, although measurements showed that the pump and motor shafts had moved laterally over $\frac{1}{16}$ in. out of alignment.

AERO-ENGINE FACTORY IN SCOTLAND.

FIG. 1. FINAL INSPECTION DEPARTMENT FOR ENGINE COMPONENTS.

AERO-ENGINE FACTORY IN SCOTLAND.

A FACTORY for constructing aircraft engines, at East Kilbride, Lanarkshire, was formally opened by the Right Hon. Duncan Sandys, the Minister of Supply, on November 20. It is leased to Rolls-Royce, Limited, by the Ministry of Supply to enable them to provide engines required under the Government's re-equipment programme for the Royal Air Force

The main block, shown in Fig. 2, on page 720, is a two-storey building with a modern facade in Portland stone, with large windows and extensive roof lights. Four workshops parallel to each other and separated by roads with grass verges are built behind it, and at the back of the workshops there is a material-receiving block and a boiler house, the interior of which is shown in Fig. 4, page 720. The boilers were supplied by John Thompson (Wilson Boilers), Limited, London-road, Glasgow, E.1, and are fitted with Hodgkinson mechanical-stokers. The architects responsible for the design of the factory were Wylie, Shanks and Wylie, of Glasgow, and the main contractors were Melville, Dundas and Whitson, Limited, 21, Blythswood-square, Glasgow.

An interesting feature of the workshop buildings are annexes which run the full length of each block to accommodate, as near to the production area as possible, ancillary services required by the machine and assembly shops. These annexes include a room for the reconditioning of tools, a sub-standards room for checking gauges, a drawing stores and an equipment stores, as well as works supervisory offices and progress offices. The four main blocks contain the machine shops, assembly shops, process plant and stores. All the workshops are illuminated with cold-cathode tubular fluorescent lamps at roof level, making unnecessary the use of local lights on machines, benches and inspection tables. The same standard of illumination is maintained for the manufacture of parts as for their inspection (Fig. 1, above, shows the final inspection department for engine components). Lighting fittings were supplied by the General Electric Company, Limited, Kingsway, Londo, W.C.2, and the Edison Swan Electric Company, Limited, 155, Charing Cross-road, London, W.C.2. The electrical contractors were James Kilpatrick and Son, Limited, Paisley.

The process block houses the heat-treatment department, the plating shop, and the tool-room. Each department has a considerable area of free floor space, giving freedom of movement. The heat-treatment section is equipped with hardening furnaces, tempering furnaces. and gas-carburising plant. The larger furnaces are arranged side by side so that they can be loaded and unloaded by means of an automatic furnace charger. The charger is in the form of a fork-lift truck, and it is mounted on a steel track set in the floor. The components to be treated are loaded on metal plates, in the form of pallets, and these are placed in the furnace together with the parts. The gas-carburising plant can carburise without the need for scaling afterwards. The plating shop, which is also in this block, is equipped for cadmium, copper and chromium plating, anodising, caustic and electrolytic etching, dichromatic treatment for magnesium castings, pickling, and electro-polishing. The plating processes and solutions are controlled by a chemical laboratory adjacent to the plating shop. The tool-room, also in this block, is equipped with Pratt and Whitney, and Oerlikon jig-borers in addition to other machinery. Adjacent to it is the main standards room, which is sound proofed and has its atmosphere controlled to a temperature of 68 deg. F. and a constant humidity.

The two centre blocks in the factory are laid out as machine shops, with general-purpose and special-purpose machines, including a combination turret lathe made by Alfred Herbert, Limited, Coventry, which is said to be the largest machine tool of its type produced in this country. Some of the cutting tools used with the Herbert lathe are cooled by carbon dioxide. The carbon dioxide is stored as a liquid in syphon bottles and is fed to the work area through two small holes drilled in the nose of the tool. At present, the holes pass through the tool shank, but holes are to be drilled through the carbide tip by the spark erosion method.

The fourth block is laid out for the assembly and repair of engines. The components are built on specially-designed stands and rotational assemblies are checked for balance on dynamic-balancing machines. The engine is assembled vertically by building from the nose towards the tail, the nose resting on a small trolley as shown in Fig. 5, page 720. Raised platforms, of the type shown on the left of the illustration, are provided along the assembly line. In the repair section, the trolleys are replaced by a platform mounted on a ram, which can be lowered into the floor sufficiently far to bring the tail-piece to the normal working level. Facilities are also provided in this section for stripping components and degreasing and checking all the parts. Rebuilding of repaired engines is planned on similar lines to new production. In an annexe of the repair department there are rigs for testing the pumps, burners, and fuel systems. These rigs are flame-proof and, in the event of a fire, fuel can be jettisoned to a room below ground level. At the end of the assembly block there are facilities for cocooning and inhibiting engines.

As parts for jet engines are produced in relatively small batches, it was not considered expedient to handle material in large quantities, as in factories which use mass-production methods. Consequently, the handling costs for the movement of parts and materials between shops could have been very high. To keep these costs to a minimum a dragline floor conveyor has been installed. The conveyor consists of a chain running below the floor level with pusher plates at 10 ft. intervals. Above the chain there is a continuous slot 1 in. wide in the shop floor. To the conveyor chain, trucks can be attached for dispatch to other departments. A signalling device on each truck enables the destination to be pre-selected, and also indicates the arrival of the truck at its destination. The conveyor is used for the issue of materials to the machine and process departments, the transport of all part-machined components between blocks and the transportation of finished parts to the stores. Where the conveyor enters or leaves a block, there are guillotine-type sliding double-doors forming an air lock. The doors are automatically lowered and raised as each truck approaches, one door shutting before the other opens, thus preventing cold air and dust being blown into the shops.

The engine test beds are among the most modern in the country. Heenan and Froude, Limited, Worcester, were the main contractors for the test plant. They recently installed similar equipment at the works of the Standard Motor Company, Limited, Coventry, and D. Napier and Son, Limited, Liverpool. Full details of the test beds at Coventry were given in ENGINEERING, vol. 175, page 588 (1953). The Rolls-Royce beds are the largest of the three installations, and they have been erected two miles away from the town and factory to avoid disturbing the local residents. Fig. 3, on page 720, shows an "Avon" engine on test.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

BORING FOR COAL AT CARDOWAN.—The sixth, and what is understood to be the last, of a series of bores being put down by the Central West Area of the Scottish Division of the National Coal Board to ascertain the extent of workable coal reserves lying south of Cardowan Colliery, Stepps, and partly within the Glasgow city boundary, has just been started. Proof of the continuity of valuable coking coals beyond a large down-throw fault has been obtained from the other bores. An earlier hope that a new colliery might be started within the city now seems likely to be abandoned in favour of driving two mines from the Cardowan workings.

DEVELOPMENTS AT CONCRETE-PRODUCT FACTORY.—Eastwoods Ltd., brick and concrete-product manufacturers have in hand a development scheme comprising extensions to their existing factory at Shewalton, Irvine, and the erection of a new building which will house plant for producing centrifugally-spun concrete pipes up to 72 in. in diameter. The firm have also entered the field of bridge construction at Dalwhinnie, constructed of prestressed concrete, and having a span of 50 ft. and a 10-ft. roadway. It is hoped to develop this type of work in the new factory.

FACTORIES IN LEITH DOCK AREA.—Three industrial undertakings are negotiating with Leith Dock Commission for the erection of factories in the Western-Harbour and Edinburgh-dock areas, it was stated on November 20, by Mr. E. W. Burness, chairman of the Commission, when presenting his review of the past year. A lease to an oil company was also being drawn up.

CLEVELAND AND THE NORTHERN COUNTIES.

LARGE ORE CARGO ARRIVES ON TYNE.—What is thought to be the biggest cargo of iron ore ever imported into the Tyne has been brought to the river by the River Afton, owned by the Ayrshire Navigation Co., Ltd., Newcastle. The vessel brought 15,000 tons from Bône, North Africa, to be discharged at the new ore-unloading quay recently completed at Tyne Dock by the Tyne Improvement Commission.

WEAR SHIPBUILDERS' ASSOCIATION CENTENARY DINNER.—At the centenary dinner of the Wear Shipbuilders' Association, held at Sunderland on November 20, Mr. R. A. Bartram, chairman of the Association, said that he felt more confident about the future of shipbuilding than he had done for some time. There was enough work to last some years and this had enabled them to put their houses in order, but they were still handicapped by taxation, lack of proper depreciation allowances, and a shortage of steel. Mr. Bartram said that the steel shortage was likely to last for another two years. Shipbuilders had been ploughing back their profits into their businesses and, despite competition from subsidised foreign concerns, he believed that Britain would be able to get a fair share of ship orders. Mr. S. Wingfield Digby, Civil Lord of the Admiralty, referred to the extent to which family firms had survived among Wearside shipbuilding concerns. He said that he had been impressed by the amount of modernisation and new methods adopted in shipbuilding on the Wear.

THE LATE LIEUT.-COL. SIR PHILIP WIGHAM RICHARDSON, BT.—We note with regret the death of Lieut.-Col. Sir Philip Wigham Richardson, Bt., O.B.E., V.D., J.P., which occurred on November 23 at his home in Weybridge, Surrey. A former chairman of Swan, Hunter, and Wigham Richardson, Ltd., Wallsend-on-Tyne, he was born at Newcastle-upon-Tyne on January 26, 1865, and was the eldest son of John Wigham Richardson, the founder of the Neptune Shipbuilding Yard and Engine Works, at Low Walker, in 1859. He was educated at Rugby and King's College, Cambridge, entered the family business in 1887, and was elected a director in 1891. He continued as a director on the amalgamation of the firm, in 1903, with C. S. Swan & Hunter, Ltd., to form the present firm of Swan, Hunter, and Wigham Richardson, Ltd. Sir Philip was elected chairman of the company in 1945 and relinquished this position on December 31, 1949, but retained his seat on the board. Sir Philip served in the Volunteers and Territorials from 1880 to 1919, received the Volunteer Officers' Decoration, and was on active service in France from 1916 to 1917. He was made an O.B.E. in 1919, knighted in 1921 and created a baronet in 1929. He was M.P. for the Chertsey Division of Surrey from 1922 to 1931.

THE LATE MR. L. MELLOR, M.B.E., M.I.E.E.—We also record with regret the death, at the age of 65, of Mr. Leonard Mellor, of Heworth, Co. Durham, area manager for North-East England and Northern Ireland for A. Reyrolle & Co., Ltd., Hebburn-on-Tyne. Mr. Mellor was due to retire next March, when he would have completed 50 years of service with the firm. He was appointed area manager in 1921 and had supervised work at several power stations in his area. He had also served the company's interests overseas. Mr. Mellor was a past chairman of the North-Eastern Centre of the Institution of Electrical Engineers.

LANCASHIRE AND SOUTH YORKSHIRE.

COLLIERY TO BE CLOSED.—Because the coal is too far out to be worked economically, it is proposed to close Rotherham Main colliery, which has an average weekly output of 2,772 tons. Only two faces in the Barnsley bed are being worked and their finish will mark the end of pit operations. The pit was sunk in the 1880's and it is stated that modernisation would be too expensive in view of the potential life of the colliery. There will be no difficulty in providing employment at other pits for the underground employees.

THE SHEFFIELD LIGHTER TRADES.—An exhibition is to be held next May at the Cutler's Hall, Sheffield, to emphasise the importance, to Sheffield's lighter industries, of packaging and publicity. The Sheffield Junior Chamber of Commerce is to sponsor the exhibition.

YORKSHIRE COAL PRODUCTION.—For the ninth week in succession Yorkshire miners have produced more than a million tons of coal; the yield in the week ended November 14 was 1,041,000 tons an increase of 10,000 tons over the previous week. The chairman of the North-East Division, Major-General Sir Noel Holmes, stated on November 14 that the Division was 300,000 tons down on the amount on the corresponding date last year. This was in spite of the fact that, in the past year, 8,000,000*l.* worth of equipment and machinery had been put in the pits, vast sums had been spent on training young men for the collieries and there were 5,000 more coal-face employees in Yorkshire than last year. The reason, he said, was absenteeism.

INQUIRY INTO LOSS OF "EMPRESS OF CANADA."—The formal investigation which was ordered by the Minister of Transport and Civil Aviation into the loss by fire of the liner Empress of Canada on January 25 last, in the Gladstone North Branch Dock, Liverpool, will open at the Royal Institution, Colquitt-street, Liverpool, 1, on December 7, at 10.30 a.m.

EXPLORATION FOR NATURAL GAS.—Exploration work for natural gas, which the D'Arcy Exploration Co., the prospecting subsidiary of the Anglo-Iranian Oil Co., are undertaking for the Gas Council, began last week at Aldburgh, in south-east Yorkshire. A seismic survey party will be working in the area for about three weeks and will then move in the direction of Market Weighton.

ALUMINIUM UNITS FOR SCHOOL BUILDING.—Newall Green Secondary School, Manchester, which was officially opened on November 10, provides an example of the use of Bristol aluminium components in conjunction with orthodox building materials. It is the first school to be built in which units, supplied by the Bristol Aeroplane Co. (Weston), Ltd., are used to provide classrooms on the first floor only, with the ground floor constructed of normal brickwork. The school has a total floor area of 57,450 sq. ft.

THE MIDLANDS.

BIRMINGHAM UNIVERSITY APPEAL FOR FUNDS.—An appeals committee, under the chairmanship of Sir Arthur Smout, has been formed by Birmingham University to raise funds to enable research work to be continued. Sir Arthur Smout said in Birmingham on November 18 that the University needs to increase its income by 75,000*l.* a year during the next seven years. Sir Arthur appealed to industry to increase its support to the University, and listed several projects which were of direct interest to industrialists, and were being delayed on account of shortage of money. Among these were nuclear research, and investigations into possible methods of reducing transport costs.

UNDERGROUND CONNECTION OF TWO COLLIERIES.—An important item in the plans of the National Coal Board (West Midlands Division) for developing existing collieries is the construction of an underground connection between two Cannock Chase pits, the Mid-Cannock and the Cannock and Leacroft collieries. Both pits date from the 1870's, though Mid-Cannock had a long period of idleness in the early days, and has only been in regular production since 1914. The pits are about ¾ mile apart. Underground connection will enable the pits to work as a single production unit having an estimated annual output of 700,000 tons of coal, to be maintained for 30 years. The development scheme includes the use of Diesel locomotives and 2¼-ton mine cars, and the conversion of the winding gear and ventilation plant at the Mid-Cannock pit to electric operation. The connecting tunnel, which was started in 1950, is nearing completion, and the electrification should be finished next year.

THE NATIONAL FOUNDRY CRAFT TRAINING CENTRE.—We have been advised by the Council of Ironfoundry Associations that the National Foundry Craft Training Centre at West Bromwich, Staffordshire, to which we referred on page 590 of our issue of November 6, is operated by a management committee of the West Midland Joint Foundry Advisory Committee (Recruitment and Training). This Committee represents the whole foundry industry, ferrous and non-ferrous. The ultimate seat of authority is the Committee of Trustees of the Centre, which similarly represents the entire foundry industry.

ROAD WIDENING IN BIRMINGHAM.—Work has started on the recently-authorised Digbeth road scheme in Birmingham. This approach to the city centre from the south-east side had been for some time the scene of the worst traffic jams in Birmingham. The road is being widened to 110 ft. with two 30-ft. carriageways, each with two lanes for moving traffic, 11 ft. wide, and a side lane, 8 ft. wide, for stopping traffic.

RAILWAY CENTENARIES.—Two Midland railway lines, which have operated in conjunction from the beginning, are a century old on December 6. They are the Shrewsbury and Hereford, and the Newport, Abergavenny and Hereford railways, the Acts of Parliament for which were passed in 1846. Both lines were formally opened on December 6, 1853. The lines eventually became vested in the Great Western and London & North Western Railways.

THE LATE MR. R. S. DYBALL.—The death has been announced, at the age of 61, of Mr. Robert Spencer Dyball, chairman of Hills (West Bromwich), Ltd., and a director of several other companies, including Constructors, Ltd., Birmingham.

SOUTH-WEST ENGLAND AND SOUTH WALES.

SHIPYARD OPENED AT NEWPORT.—The only new shipyard to be built in this country during the past 25 years was officially opened at Newport on November 27 by Sir David Maxwell Fyfe, Home Secretary and Minister for Welsh Affairs. It has been promoted by Group-Captain George Bailey and in the opinion of Sir Ralph Cochrane, chairman of the proprietors, the Atlantic Shipbuilding Company, will be able to compete very favourably for orders with European shipyards. Last June the company secured an order for two wood-pulp carrying ships for the Quebec and Ontario Transportation Company, each of which will be 253 ft. 3 in. long with a beam of 43 ft. 10 in. The ships will be prefabricated in sections in the shop and erected in the dry dock. They will then be floated and moved to a fitting-out basin in Newport Docks. It is expected that 400 men will be employed on completion of a dry dock large enough to build prefabricated ships of up to 40,000 tons.

WELSH COAL INDUSTRY.—In the week ended November 14 the production of coal in South Wales reached its highest level since the week just before Christmas of last year. The amount produced was 513,524 tons. Man-power was 102,442 compared with 103,857 last December. The Tor-y-Graig Colliery at Bryncoch, near Neath, which has been closed since the coal strike of 1926 is being brought back into production. Mr. Craven Llewelyn and his two brothers, Mr. Ivor Llewelyn and Mr. Gildas Llewelyn bought the colliery in January, 1952, and secured a lease for a first period of 10 years from the National Coal Board. In February, 1952, they began clearance work underground, and, after overcoming several obstacles, struck a coal seam recently.

STEEL PIPES FOR ALASKA.—Part of a 1,000,000*l.* order for steel pipes, secured by Stewarts and Lloyds Ltd., will be executed at the firm's Newport works. The pipes will be part of an oil line, 610 miles in length, connecting British Columbia and Alaska. This is one of the largest dollar orders received by the firm. It is referred to under "Contracts" on page 728.

MOORING EQUIPMENT FOR RANGOON.—Brown Lenox & Co., Ltd., Pontypridd, have dispatched about 225 tons of mooring equipment to Rangoon under an American Aid scheme. The order comprises large cast-steel chain-cable of 3-in. and 3⅛-in. diameter, and eight 6-ton single-fluke anchors. It is the heaviest single shipment yet made from the works.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Monday morning in the week preceding the date of the meeting.

INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, December 7, 5.30 p.m., Victoria-embankment, W.C.2. Discussion on "The Ridley Report," opened by Mr. C. T. Melling. *South Midland Centre:* Monday, December 7, 6 p.m., James Watt Memorial Institute, Birmingham. "Radio Aids for Airport Control," by Mr. E. J. Dickie. *Mersey and North Wales Centre:* Monday, December 7, 6.30 p.m., Royal Institution, Colquitt-street, Liverpool. "Research in the Electrical Manufacturing Industry," by Mr. L. J. Davies. *Measurements Section:* Tuesday, December 8, 5.30 p.m., Victoria-embankment, W.C.2. (i) "Determination of Optimum Process-Controller Settings and Their Confirmation by Means of an Electronic Simulator," by Mr. R. L. Ford; (ii) "Effects of the Addition of Nonlinear Elements on Transient Performance of a Simple R.P.C. System Possessing Amplifier Saturation," by Dr. J. C. West, Mr. J. L. Douce and Mr. R. Naylor; and (iii) "The Step-Function Response of an R.P.C. Servo-Mechanism Possessing Torque Limitation," by Dr. J. C. West and Mr. I. R. Dalton. *North Midland Centre:* Tuesday, December 8, 6 p.m., The University, Leeds. "Applications of Electronics," by Dr. T. G. Bridgwood. *Education Discussion Circle:* Wednesday, December 9, 6 p.m., Victoria-embankment, W.C.2. Discussion on "Teaching of Electrical Machine Design," opened by Professor M. G. Say. *Utilisation Section:* Thursday, December 10, 5.30 p.m., Victoria-embankment, W.C.2. "Electric Lifts in Post-War Housing," by Mr. C. G. L. Morley.

SOCIETY OF ENGINEERS.—Monday, December 7, 5.30 p.m., Geological Society's Apartments, Burlington House, Piccadilly, W.1. "Resistance Welding in Relation to the Automobile Industry and Modern Welding Trends in Light-Alloy Welding," by Mr. C. E. Slade.

INSTITUTION OF MECHANICAL ENGINEERS.—*North-Eastern Branch:* Monday, December 7, 6 p.m., Neville Hall, Newcastle-upon-Tyne. Thomas Hawksley Lecture on "Relaxation Methods: A Retrospect," by Sir Richard Southwell, F.R.S. *South Wales Branch:* Tuesday, December 8, 6 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "Refinery Expansion Project at Llandarcy," by Mr. I. Cameron. *Eastern Branch:* Wednesday, December 9, 7.30 p.m., Great White Horse Hotel, Ipswich. "Industrial Gas Turbines," by Mr. H. N. G. Allen. *East Midlands Branch:* Wednesday, December 9, 7.30 p.m., County Technical College, Newark-on-Trent. "Researches into Machinability of Steel," by Mr. K. J. B. Wolfe. *Yorkshire Branch:* Thursday, December 10, 7 p.m., The University, Leeds. Thomas Hawksley Lecture. *Institution (Education Group):* Friday, December 11, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. Four papers on "Practical Training in Industry for the Graduate in Mechanical Engineering," by Mr. K. R. Evans, Mr. H. W. Fulton, Mr. R. S. Medlock, Mr. D. P. Lant and Professor J. A. Pope. AUTOMOBILE DIVISION.—Tuesday, December 8, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. "Functions of Materials in Bearing Operation," by Mr. P. P. Love, Mr. P. G. Forrester and Mr. A. E. Burke.

ROYAL SOCIETY OF ARTS.—Monday, December 7, 6 p.m., John Adam-street, W.C.2. Cantor Lecture. "Alloys—III," by Mr. G. L. Bailey. Wednesday, December 9, 2.30 p.m., "The Seed Crushing Industry," by Dr. E. G. Woodroofe.

CLEVELAND INSTITUTION OF ENGINEERS.—Monday, December 7, 6.30 p.m., Cleveland Scientific and Technical Institution, Middlesbrough. "Gasholders," by Mr. T. H. Riley.

JUNIOR INSTITUTION OF ENGINEERS.—*North-Western Section:* Monday, December 7, 7 p.m., Engineers' Club, Manchester. "Shell Moulding," by Mr. F. Burgess. *Institution:* Friday, December 11, 7.30 p.m., Royal Society of Arts, John Adam-street, W.C.2. Presidential Address on "Development and Future Possibilities in Electricity Generation," by Sir John Hacking.

INSTITUTION OF THE RUBBER INDUSTRY.—*Preston Section:* Monday, December 7, 7.15 p.m., Bull and Royal Hotel, Preston. "Glass Fibres as Reinforcements in Rubber and Plastics Industries," by Mr. A. M. Dobson. *London Section:* Tuesday, December 8, 5 p.m., 26, Portland-place, W.1. (i) "Cyclised Rubber," by Mr. E. P. B. Edwards; and (ii) "Collection, Grading and Packing of Rubber in Malaya," by Mr. F. R. Horridge.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS.—Monday, December 7, 7.30 p.m., College of Commerce and Technology, Pond-street, Sheffield. "Shell Moulding," by Mr. J. Fallows.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*Scottish Centre:* Monday, December 7, 7.30 p.m., 39, Elmbank-crescent, Glasgow. "Hydraulic Servo Systems for Heavy Commercial Vehicles," by Mr. J. St. H. Webb. *Midlands Centre:* Tuesday, December 8, 7.30 p.m., Crown Inn, Birmingham. "Lead-Acid Batteries," by Mr. E. Chapman.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—*Leeds Branch:* Monday, December 7, 7.30 p.m., Great Northern Hotel, Leeds. "Miniature Circuit Breakers," by Mr. N. W. Woof.

INSTITUTION OF CIVIL ENGINEERS.—*Structural and Building Division:* Tuesday, December 8, 5.30 p.m., Great George-street, S.W.1. "A Moment Distribution Method for the Analysis and Design of Structures by the Plastic Theory," by Dr. M. R. Horne. *Midlands Association:* Thursday, December 10, 6 p.m., James Watt Memorial Institute, Birmingham. "New Bridges in Germany," by Mr. C. S. Chettoe. *North Western Association:* Thursday, December 10, 6.30 p.m., Engineers' Club, Manchester. "Construction of Three-Storey Warehouse in Prestressed Concrete," by Mr. R. W. Pearson.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, December 8, 5.30 p.m., 85, The Minories, E.C.3. "The Influence of Modern Refinery Technique on Marine Fuel Oil Quality," by Mr. C. W. G. Martin.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Wales and Monmouthshire Branch:* Tuesday, December 8, 6.30 p.m., Mackworth Hotel, Swansea. Film Evening.

INSTITUTION OF WORKS MANAGERS.—*Birmingham Branch:* Tuesday, December 8, 7 p.m., Grand Hotel. "Industrial Relations," by Mr. F. V. Everard.

INCORPORATED PLANT ENGINEERS.—*Manchester Branch:* Tuesday, December 8, 7.15 p.m., Engineers' Club, Manchester. "Mobile Plant," by Mr. J. L. Sturrock. *East Midlands Branch:* Wednesday, December 9, 7 p.m., Offices of East Midlands Gas Board, Nottingham. "The Failure of Metals," by Professor J. A. Pope.

INSTITUTE OF FUEL.—*North-Western Section:* Wednesday, December 9, 2 p.m., Engineers' Club, Manchester. "Work of a Central Fuel Technology Department," by Mr. G. Nonhebel. (Luncheon, 1 p.m.) *Yorkshire Section:* Wednesday, December 9, 6.30 p.m., The University, Sheffield. "Fans," by Mr. D. S. Macfarlane.

ROYAL UNITED SERVICE INSTITUTION.—Wednesday, December 9, 3 p.m., Whitehall, S.W.1. "Effects on Human Body of High-Altitude and High-Speed Flight," by Group Captain W. K. Stewart.

BRITISH INSTITUTION OF RADIO ENGINEERS.—*North-Eastern Section:* Wednesday, December 9, 6 p.m., Neville Hall, Newcastle-upon-Tyne. "Effects of Aural Disturbances on Audio Production," by Dr. M. Anderson. *London Section:* Wednesday, December 9, 6.30 p.m., London School of Hygiene, Keppel-street, W.C.1. Symposium on "Vibration Methods of Testing."

LIVERPOOL ENGINEERING SOCIETY.—Wednesday, December 9, 6 p.m., 24, Dale-street, Liverpool. "Power Station Design and Construction," by Mr. W. H. C. Pilling.

REINFORCED CONCRETE ASSOCIATION.—Wednesday, December 9, 6 p.m., 11, Upper Belgrave-street, S.W.1. "Partially Prestressed Concrete," by Dr. P. W. Abeles.

INSTITUTION OF ENGINEERS-IN-CHARGE.—Wednesday, December 9, 6.30 p.m., St. Bride Institute, Fleet-street, E.C.4. "Safety in Factories," by Mr. H. E. Entwistle.

SOCIETY OF CHEMICAL INDUSTRY.—*Corrosion Group:* Wednesday, December 9, 6.30 p.m., Chemical Society's Apartments, Burlington House, Piccadilly, W.1. Two papers on "Protection of Metal by Paint."

INSTITUTION OF PRODUCTION ENGINEERS.—*Preston Section:* Wednesday, December 9, 7.15 p.m., Crown Hotel, Blackburn. "Production Engineers of the Future," by Mr. E. C. G. England. *Coventry Section:* Thursday, December 10, 7 p.m., Geisha Café, Coventry. "Labour Incentive Systems," by Mr. N. A. Dudley.

INSTITUTION OF SANITARY ENGINEERS.—Thursday, December 10, 6 p.m., Caxton Hall, Victoria-street, S.W.1. Discussion on "Engineering Problems Concerning Treatment of Trade Effluent."

INSTITUTE OF WELDING.—*South London Branch:* Thursday, December 10, 6.30 p.m., 2, Savoy-hill, W.C.2. "Hydrogen versus Welding," by Dr. C. L. M. Cottrell.

WOMEN'S ENGINEERING SOCIETY.—*London Branch:* Thursday, December 10, 7 p.m., 35, Grosvenor-place, S.W.1. "Motor-Car Racing and Car Trials," by Mr. S. H. Allard.

LIVERPOOL METALLURGICAL SOCIETY.—Thursday, December 10, 7 p.m., 24, Dale-street, Liverpool. "Bearings and Bearing Alloys," by Mr. P. T. Holligan.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, December 11, 6.15 p.m., Mining Institute, Newcastle-upon-Tyne. "Vibration Tests on an Up-River Collier," by Mr. A. J. Johnson and Mr. W. J. Marwood.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Scottish Branch:* Saturday, December 12, 3 p.m., Royal Technical College, Glasgow. "Production of Non-Ferrous Valves and Plumbing Fittings," by Mr. E. C. Mantle.

BALL-BEARING FACTORY: ERRATUM.—We regret that the article on the new factory of Ransome & Marles Bearing Co., Ltd., which appeared on page 555, *ante*, contained certain errors. It is not practicable to detail these errors in this paragraph.

PERSONAL.

H.R.H. THE DUKE OF EDINBURGH, K.G., K.T., has accepted Honorary Membership of the Institution of Mining Engineers, 436, Salisbury House, Finsbury Circus, London, E.C.2.

MR. W. LYONS, chairman and managing director of Jaguar Cars Ltd., has been elected President of the Motor Industry Research Association, in succession to SIR REGINALD ROOTES, deputy chairman, Rootes Group, who has held that office for the preceding two years.

MR. J. R. KELLY, who as announced on page 687, *ante*, joined the board of Vickers-Armstrongs Ltd., on December 1, at the same time became a director of Powers-Samas Accounting Machines Ltd., G. J. Worssam & Son Ltd., and A.B.C. Motors Ltd., all companies of the Vickers Group.

MR. S. N. TURNER has resigned from the board of the Staveley Coal and Iron Co. Ltd., and DR. J. E. HURST has been elected a director in his place.

MR. G. R. WHITEHEAD, manager of the Spotborough foundry, Doncaster, of John Fowler and Co. (Leeds) Ltd., Hunslet, Leeds, 10, has been elected a director of the company.

MR. J. SMILLIE, area general manager, Cannock Chase, West Midlands Division, National Coal Board, has been appointed production director of the Division.

MR. A. W. DANIELS, M.I.Mech.E., has been appointed managing director of Holdan Engineers (London) Ltd., 49, St. James's-street, London, S.W.1.

MAJOR V. R. BARRON, managing director of Purdy Machinery Co. Ltd., subsidiary company of Farrow & Jackson and Purdy Ltd., has retired owing to ill health after an association with the company of over 30 years.

MR. JAMES BLACK, M.B.E., a member of the technical staff of the North British Locomotive Co. Ltd., Glasgow, has retired after 59 years of service with the firm.

MR. E. A. O'NEAL, JR., chairman of Monsanto Chemicals Ltd., has been elected, in addition, a vice-president of the Monsanto Chemical Co., St. Louis, Missouri, U.S.A.

MR. NORMAN MOSELEY, A.M.I.Mech.E., has been appointed a certifying officer, Ministry of Transport, in the Metropolitan traffic area. He takes up his duties on December 14.

MR. E. F. WARD has been made assistant manager, contracts department, Johnson and Phillips Ltd., Charlton, London, S.E.7.

MR. RALPH FENWICK has recently joined the Telegraph Construction and Maintenance Co. Ltd., Telcon Works, Greenwich, London, S.E.10, as technical sales representative for the North-Eastern area. He was formerly development manager with Morganite Resistors Ltd.

MR. JOHN C. SMITH, district manager for Mavor and Coulson Ltd., for mining machinery in Northumberland and Durham, is retiring on December 31 after 32 years of service with the company. His successor is MR. J. H. ROGAN, whose office will be at 1, Eldon-square, Newcastle-upon-Tyne, 1.

MR. ALAN HESS, late public relations officer of the Austin Motor Co. Ltd., has joined the board of Portable Balers Ltd. as sales director. He will also be in charge of public relations for this company and Aldis Brothers Ltd., Aero Heat Treatments Ltd., Hard Coating Ltd. and Hawkes and Snow (Curtaincraft) Ltd.

JOHN FOLKES (LYE FORGE) LTD., Stourbridge, Worcestershire, have acquired the business of FELLOWS BROTHERS LTD., Cradley Heath, Staffordshire, makers of chains and lifting tackle.

The head offices of W. J. FRASER & Co. LTD., chemical-engineering contractors, are now at Harold Hill, Romford, Essex.

As from December 7, the London plant branch office of Crompton Parkinson Ltd. will be moved from Crompton House, Aldwych, W.C.2, to 1-3, Brixton-road, S.W.9. (Telephone: RELiance 7676.)

Following the award of a Royal Charter to their parent company in Amsterdam, the NETHERLANDS HARBOUR WORKS CO. (LONDON) LTD., 4C, Dryden Chambers, 119, Oxford-street, London, W.1, have changed their name to ROYAL NETHERLANDS HARBOUR WORKS CO. (LONDON) LTD.

An American firm, PORTER INTERNATIONAL CO., 1025, Connecticut-avenue, N.W., Washington 6, D.C., U.S.A., has been formed to specialise in the international exchange of manufacturing rights. The firm is specially interested in securing United States manufacturing rights for new products of British design in the fields of mechanical and electrical engineering, chemistry, electronics and aircraft.

The address of the INSTITUTION OF HEATING AND VENTILATING ENGINEERS is now 49, Cadogan-square, London, S.W.1. (Telephone: SLOane 1601 and 3158.)

AERO-ENGINE FACTORY IN SCOTLAND.

(*For Description, see Page* 717.)

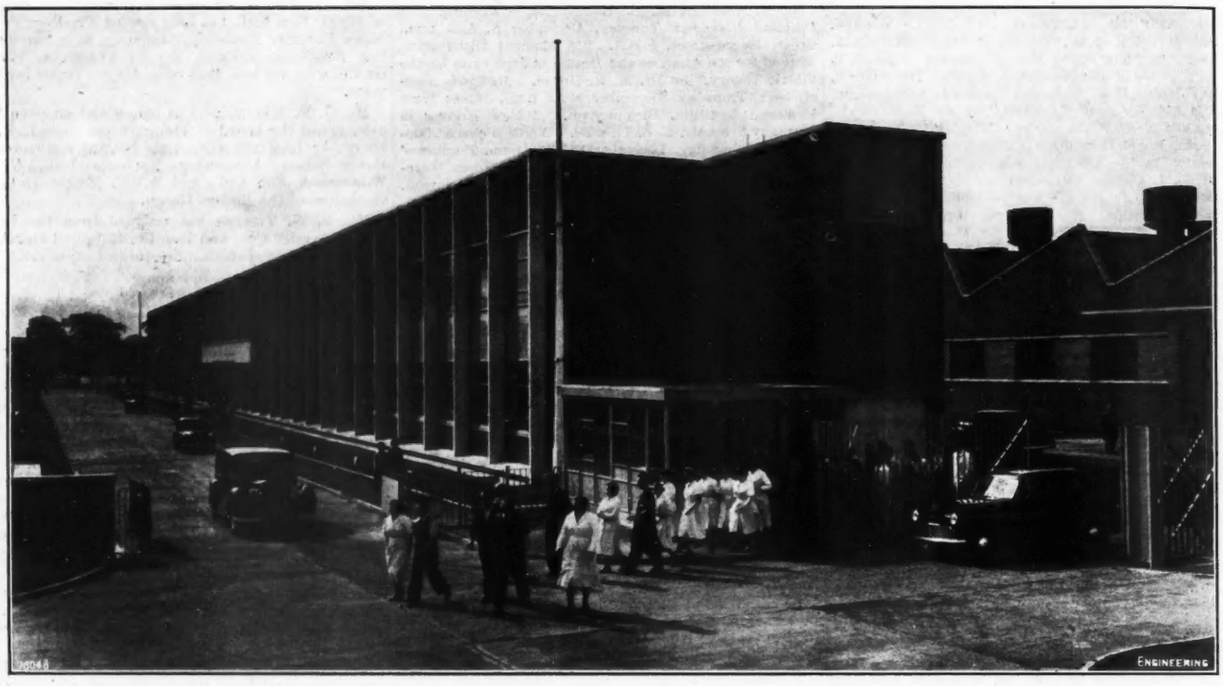


FIG. 2. TWO-STOREY OFFICE BLOCK AND MAIN ENTRANCE.

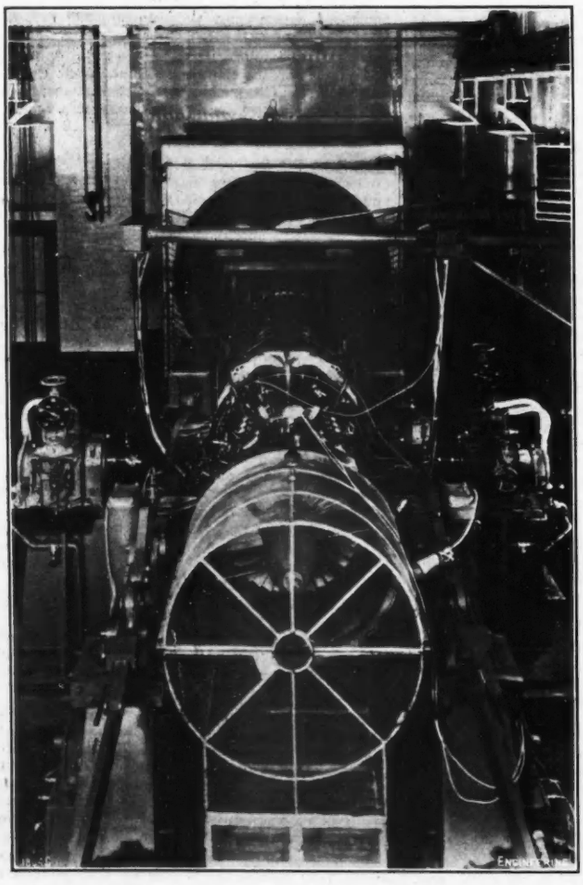


FIG. 3. "AVON" ENGINE IN TEST CRADLE.

FIG. 4. BOILER HOUSE, SHOWING MECHANICAL STOKERS.

FIG. 5. ENGINE ASSEMBLY LINE.

ENGINEERING

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

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ENGINEERING

FRIDAY DECEMBER 4, 1953.

VOL. 176. No. 4584.

THE FUTURE OF THE BRITISH INDUSTRIES FAIR.

IN April, 1952, the Exhibitions Advisory Committee of the Board of Trade were asked to consider the future organisation of the British Industries Fair, with special reference to the basis on which it should be continued. The fact that this inquiry had been instituted, it may be recalled, led to a good deal of discussion, not always well-informed, and was probably the root cause of the rumour which gained considerable currency about twelve months ago, to the effect that the 1953 Fair might be the last. Evidently those who spread that rumour had not studied the Committee's terms of reference, which quite clearly indicated that the Fair should continue; no other course appears to have been contemplated. The immediate outcome of the Board's request was the appointment of an *ad hoc* sub-committee of the Exhibitions Advisory Committee, whose report has now been published as a Command Paper.*

The sub-committee, under the chairmanship of Sir Ernest Goodale, C.B.E., M.C., had not only a general instruction "to review the present arrangements" for the Fair, but the more specific request to advise the President of the Board of Trade on three points, namely, "(i) Whether, in the light of recent experience, any changes in purpose, character, scope and location of the Fair are called for; (ii) whether it is desirable and practicable that responsibility for the organisation and administration of the Fair should be assumed in full or in part by industrial and commercial interests and, if so, to recommend on what basis this should be done; (iii) the general financial aspects of the Fair, including the amount which should be spent on publicity." In their study of these questions, the sub-committee received evidence from the Association of British Chambers of Commerce, the Federation of British Industries, the National Union of Manufacturers, the Trades Union Congress, the Commonwealth Section of the British Industries Fair, the Director of the Council of Industrial Design, and "three experts with experience of Fair publicity," in addition to officials of their own Department. Some of the evidence, it appears, "confirmed the impression that the Fair has been losing ground in the eyes of both buyers and exhibitors." We are interested to note that "this trend has been particularly noticeable at the London section," a comment which leads us to wonder how intensively the sub-committee prosecuted similar researches in the Engineering Section, which is probably the least conveniently situated of any from the point of view of access, and one of the most expensive to maintain because it requires the presence of technical staff in many cases.

In the space given to the London section of the Fair, however, by comparison with the references to the Birmingham section at Castle Bromwich, the report is more than a little out of balance. We may be biased in this regard, bearing in mind that the concern of this journal is principally with the Engineering Section, in which ENGINEERING has had a stand for many years; but it is a fact that the Birmingham part of the Fair receives only brief mention, whereas the future of the London portion evidently occupied the sub-committee's time to a considerable extent. The reason may be that, as stated in the report, "the Birmingham section . . . is organised by the Birmingham Chamber of Commerce through a separate board of management which accepts full responsibility, apart from publicity, for the finances" of that section and that the sub-committee, aware of the weaknesses of Civil Service administration as applied to Fair management—which they admit—felt that they were not in a strong enough position to criticise Castle Bromwich. At all events, they are content to recommend, without further comment, that this "large and self-supporting and separate section . . . should remain where it is," and under the same management as hitherto.

The other main recommendations in the report are that, while it is not economically justifiable at present to erect special buildings solely for the benefit of the London section of the Fair, "any development concerning the erection of exhibition buildings on the Crystal Palace site should be closely followed"; that a public corporation should be established to take over from the Board of Trade its present responsibility, "as from and including the 1955 Fair"; and that the Government should furnish certain financial guarantees for the operations of the corporation during its first five years, and should finance publicity for the Fair, at home and overseas, up to specified amounts. The figures mentioned in these recommendations are 100,000*l.* over five years for the corporation's working capital and "provision against possible losses during its early years," 100,000*l.* per annum for overseas publicity—certainly for five years, but apparently without an ultimate time limit—and 50,000*l.* and 30,000*l.* for home publicity for the Fairs to be held in 1954 and 1955, respectively.

The proposed corporation, it is recommended, should be formed under the Companies Act as a company limited by guarantee and should have a board of directors numbering not more than seven. These should comprise the chairman—"who should be a prominent industrialists who could command support for the project"—four independent members,

* *Report of the Sub-Committee of the Exhibitions Advisory Committee to review the Present Arrangements for the British Industries Fair.* Cmd. 9013. H.M. Stationery Office. [Price 6d. net.]

a representative of the Birmingham Chamber of Commerce, and a Government nominee. The power to appoint (and remove) the chairman and the four independent members, it is suggested, should be vested in three trustees, namely, the Presidents for the time being of the Association of British Chambers of Commerce, the Federation of British Industries, and the National Union of Manufacturers. The opinion is expressed that the independent members should include a leading exhibitor and a financial expert.

The paragraph in the report which recommends the establishment of the corporation also outlines its functions, but on this point the sub-committee are rather less specific and clearly envisage the possibility that the Fair may not always consist of the three main exhibitions—Earl's Court and Olympia in London, and Castle Bromwich in the Birmingham area—which now form the familiar arrangement. "The proposed corporation," it is stated, "should be empowered to do more than develop the London section; it should be a national corporation which would be responsible for co-ordinating policy with regard to the Fair as a whole, with power to delegate to sections the management of such sections," including "any other additional sections which might develop"—but always "leaving the management of the Birmingham section to the Birmingham Chamber of Commerce." A paragraph that should be of some interest to professional organisers of exhibitions proposes that the corporation "should be empowered to consider applications for affiliation to the British Industries Fair by sponsors of specialised trade fairs, whether held at the same time as the British Industries Fair or at different times of the year and in various parts of the country." Moreover, it "should be empowered to extend the scope of the Fair if it so thought fit"; no definite recommendation is made on this point, but the report admits that the sub-committee did consider the possibilities of making the Fair fully international, and of including commercial firms from the British Commonwealth in the appropriate trade sections.

When the publication of this report was announced, we entertained some hopes that, at long last, some of the causes of criticisms that we and others have levelled at the B.I.F., especially from the viewpoint of the engineering section of it might be tackled seriously and even removed; but so far as the engineering part of the Fair is concerned, there is little to sustain such hopes. In fact, there is no indication whatever that the present shortcomings at Castle Bromwich are even recognised to exist. We discussed them at length in our issue of May 12, 1950, and they need not be recapitulated in detail; but many of them, as we then pointed out, could be overcome with comparatively little trouble and expense, and, we are convinced, with distinct advantage to the Fair and to British industry. Most of them are merely matters of obviating discomfort and inconvenience, so that the visitor who has been there will look forward with pleasure to the next occasion. The handicap of the situation of the Fair building is a more difficult problem to solve, and one of the first hurdles to be overcome is the shortage of suitable hotel accommodation. Birmingham's hotels have long been inadequate for the ordinary business needs of the city, without the peak load that the Fair ought to represent. This is, of course, a matter outside the power of a Fair corporation to correct by direct action, but the commanding industrialist chairman, backed by four really independent members and the Chamber of Commerce, should be able to exert some useful influence. If so, the Fair will have a better chance to succeed than it has ever had, and may realise even yet the sub-committee's dream that "it should project British industry on the world and be a pageant of the best in British industry."

FORM AND FUNCTION.

THE architect and the engineer—which of the two poses the greater problems for the other? The architect, being concerned mainly with the form of a structure, sometimes expects the engineer to concede too much in the way of design. The engineer, especially if he lacks a sense of architecture, may regard the architect as unreasonable (and so, in a sense, he is, since he is not guided solely by his reason). To-day, however, there is a more intractable factor in the relationship: engineering research and inventiveness are thrusting into the hands of architects such a proliferation of new materials and techniques that architects are hardly able to digest them and yet design wholly satisfying forms. That is the greatest problem in the relationship to-day, and architects are very conscious of it.

A machine in which every component of the design, every dimension and every shape, is determined by strictly functional considerations, often excites a sense of wonder in the beholder. Who has not admired the form and finish of a modern jet engine? With machines requiring such calculated precision, it is clear that the engineering designer is not incapable of creating a thing of beauty. It is when engineering design is only partly determined by function that the engineer may be uncertain of his power to design satisfactorily. If it is a machine of some kind that he is developing he may seek the assistance of an industrial designer, but if it is a structure or a building he co-operates with an architect. It is not many years, in the historical sense, since one man was both architect and engineer, but the complexity of the new materials and techniques seems to have ended all hope of a return to that ideal arrangement, except in the case of a few exceptional men.

Modern developments in design and construction have helped the structural engineer. If they have not always simplified his task they have extended the bounds of the practicable. There is, indeed, the risk of employing a new way simply for the sake of being new (though that is not necessarily a fault or in bad taste—the architect may consider that the subject demands an original treatment). The developments which have thus given the engineer a new freedom have confronted the architect with a bewildering choice. No longer able to follow the traditional teaching of his profession he is thrown back on the absolute fundamentals of his art. He must think afresh; his art must be born again. And all the while he must build not to please himself, but to satisfy the authority which has engaged him, and to delight, shock or placate the untutored but outspoken public which is, at least temporarily, his judge.

Art is greatest when it uses the simplest materials. Stone, bronze, colours, plaster, wood, ceramics—these are the elemental media which, because they are simple, artists have worked with. It is as though art flourishes most when the scope of the medium is most restricted. That is why to-day architects are faced with the most formidable problems their profession has ever experienced. When there are innumerable ways of achieving stability and ensuring convenience in a building, and when many of those ways are new and untried in that context, it is hard indeed for the architect to resolve the problem of form. Even if he is a genius, and creates a work which a hundred years hence is hailed as the design which pointed the way to all subsequent development, it is more than likely that in his day he will be assailed by his colleagues or ridiculed by contemporary laymen. It is a tremendous challenge, and even if he succeeds in meeting it he must be prepared to educate society to accept his aesthetic faith.

That is, perhaps, his fundamental problem. Throughout history men have been able to base their aesthetic judgment mainly on the standards that were accepted and preserved by their fathers. "The child is father of the man"—and it is convenient for the man if change is not so rapid as to prevent him from using the aesthetic sense he learnt as a child. But when the pace of change quickens, when old traditions lose all their force in a generation and every fresh wave of the advancing tide brings new ideas, then the man can no longer view the works of the newcomers and judge them with calm and deliberate assurance. His reaction, almost invariably, is to disguise his uncertainty by a gruff condemnation. How much better it would be if he were to make an effort to grasp the significance of the new materials and techniques and judge contemporary design accordingly. But that is hardly likely, except among a minority. The adventurous architect who has developed a new synthesis is thus building for a public which will not understand him, though he hopes for the day when his language of form will communicate his meaning without need of interpretation.

While architects are feeling their way towards a new "universal," the engineers who are the cause of all the trouble can undoubtedly help or hinder the evolution. They will be able to help to the extent that they are in sympathy with the mind of the architect, and only if the architect is able to communicate his ideas to the engineer. A fusion of the two skills will not be something new. It is only during the past two hundred years—since the Industrial Revolution—that they have been separate. One consequence of that separation was noted by Professor Robert H. Matthew, formerly architect to the London County Council, in his recent inaugural address in the Chair of Architecture at Edinburgh University. "One consequence," he said, "has been the inability of the architect, because of his lack of structural knowledge, to take advantage of new structural techniques; and it seems equally to have resulted in the inability of the engineer, who has become absorbed in mathematical analysis and calculation, to use his developing knowledge of the possibilities of structural design to create imaginative form." It was not so long ago, he added, that Telford designed both bridges and buildings; Wren had considered himself as much an engineer as an architect, and that to-day we made no distinction between the aqueducts, the triumphal arches and the villas of Roman times.

Professor Matthew believes that the introduction of the technique of industrial engineering into building practice in recent years may encourage architects and structural engineers to come together at the vital designing stage when their minds can bear simultaneously on the same problem. A common education for the architect and the structural engineer, though it has been done abroad, is not likely to be adopted in this country. Liaison between the two professions is therefore important, he believes, in experimental building, and one of the advantages of the continuing programme of building which public authorities usually command is that full-scale experiment can be carried out over a period of years. Experimental buildings should be designed in prototype (just as prototype machines are designed) because of the extension of the use of machines in the assembly of parts of buildings, and the widened range of new materials available to the architect. "Practical experiment, however, must take place on the basis of theoretical study." It is in this respect, clearly, that Professor Matthew sees room for improvement. He deplores the fact that, at present, there is almost no post-graduate research work taking place in any university architectural department in this country, and he regards it as a contributory factor in the present slow evolution of building technique. If this gap is filled—Professor Matthew has evidently set his heart on filling it—it may be that post-graduate

courses for architects and engineers working together will hasten the desired integration of architectural form and structural function. Men who have had several years' experience of practical work and responsibility will be better fitted to achieve mutual understanding and thus create new, appropriate and imaginative designs.

It will then be the rule, not the exception, to design buildings and structures in which convenience in function, stability of the structure, and delight in form are intermingled as in the creations of Nature. How far engineers and architects have fallen short of this ideal in the past was pointed out, in an admirable example, by a past-president of the Royal Institute of British Architects, Mr. H. S. Goodhart-Rendel, in a lecture he gave at Cambridge University in 1941. He recalled the design of an "astonishing railway station" at Gourock, in Scotland. "Here an ordinary collection of glass-roofed sheds was enclosed in red brick walls, supporting numbers of half-timbered gables complete with bargeboards and domestic windows. In producing such a monstrosity the engineer and the architect might have worked on different planets for all the converse they can have had together. Yet what an interesting time they might have had working together to produce the ideal terminus on a quay, the railway terminus on a quay that would have looked like a railway terminus on a quay, and like nothing else." The fact that an architect can make such a comment is an indication of the progress that has been made since the Nineteenth Century: a railway station on a quay to-day must look like a railway station on a quay. The architect's problem is now to evolve the appropriate forms for every new building and structure, and in that task he will be helped immeasurably by the engineer who can appreciate form as well as function.

NOTES.

CONFERENCE ON TECHNOLOGICAL EDUCATION.

THERE are now 40 research associations operating under the aegis of the Department of Scientific and Industrial Research, and collectively they form probably the most important group of employers of young research workers in the country. They have a direct interest, therefore, in the ability of the nation's universities and technical colleges to produce a sufficient number of graduates possessing the qualifications that industry needs if it is to keep ahead or even abreast of competitors in the industrial application of science. For the ventilation of possibly divergent views of how this ability could best be enhanced, the chairmen and directors of the 40 research organisations held a conference in London on November 27. The discussions were intended to be informal and it was considered advisable, therefore, that the proceedings should be private; but, at the luncheon held in connection with the Conference, some general observations on the subject were made by the chairman, Sir Ian Heilbron, F.R.S., when introducing Lord Woolton, the principal guest, who deputised for Lord Salisbury, the Lord President of the Council. Sir Ian, in his remarks, referred to the rôle of the research associations in promoting the technical education of their own staffs, providing education in special subjects through the medium of their staffs, and by encouraging extra-mural research; and to the scheme for expanding the present facilities for the acquisition of technological education and training—for example, the enlargement of the Imperial College. Lord Woolton, in his speech, expressed the opinion that, in industry generally, science was neither understood nor appreciated as it should be. Germany, he declared, had excelled every nation in the world in the application of science; Japan, which had a larger population than Great Britain, was making great efforts to compete in world markets; and the United States also had developed technology to a much greater extent than Britain had done. Yet, he continued, there was no doubt about Britain's ability to excel in the same direction if only the whole of the country's resources, mental as well as material, were applied to that end. "Let us," he said, "be both broad and liberal in our technological education—but not too liberal, nor so broad as to lose the cutting edge. Let us give a chance to the man of narrow interests to study those interests and, later, to say that he has a degree—a degree of university status."

LEGISLATION ON INVENTION AND DESIGN.

A Bill entitled "Inventions and Designs (Crown Use) Bill," which came up for a second reading in the House of Lords on Tuesday, has for its purpose the replacement by permanent legislation of certain emergency provisions relating to these subjects. It consists of four principal clauses, the first of which deals with the existing powers of the Government to use patented inventions and registered designs "for the services of the Crown," and lists a number of specified purposes, which are to be treated as included among the objects for which inventions may be so used. In particular, it enables the Government to dispose freely of defence materials and surplus goods, besides using them in connection with the national health, civil defence and fire services. The second clause enables a Government department to authorise a contractor to use inventions and designs which are not patented or registered, irrespective of any existing agreement, while the third empowers the Minister of Supply and the Admiralty to demand the disclosure of information relating to any invention or design (whether or not patented or registered) if it appears to be necessary for defence purposes. The remaining operative clauses provide penalties for refusal to disclose the desired information and make provision for the settlement of disputes about compensation. The Bill therefore envisages a profound change in an important field of industrial relations and, what is more disturbing, it has been brought forward without previous consultation with industry, as was pointed out by Mr. P. E. Lincroft, secretary of the Chartered Institute of Patent Agents, in a letter to *The Times*. Such behaviour on the part of Government departments is not, of course, unknown and may perhaps be explained, in this instance, by the assumption that those who drafted the Bill were not altogether aware of what they were doing. As Mr. Lincroft says, the effect of this clause may be more far-reaching even than those which are apparent at first sight, because it gives the departments almost unlimited power to extract information about manufacturing processes and techniques. The terms of the measure are, in fact, too wide and we hope that its contents will receive the most critical consideration, especially as regards its effects on the well-being of the country and the relationship of British industrialists with foreign concerns. This is quite feasible, since there is no hurry in the matter, the existing emergency powers having been extended to December, 1954.

CALCULATION OF THE THICKNESS OF HIGH-TEMPERATURE STEAM PIPES.

TO THE EDITOR OF ENGINEERING.

SIR,—Dr. J. S. Blair departs to some extent from conceptions which are now gaining acceptance internationally, in his article on the thickness of high-temperature steam pipes on page 549, *ante*. May I give my own views on the calculation of thick-walled pipes?

As soon as creep starts, there is no tendency for the hoop stress to equalise itself across the thickness and to become equal to the thin-cylinder stress $\frac{P\,d}{2\,t}$, where d is the bore. The creep or flow starts on the inside, due to excessive shearing stresses, and spreads through the wall in accordance with the law $s_t - s_r = s_0$, where s_t = tangential stress, s_r = radial stress, and s_0 = yield limit. This law of plasticity is the correct one, which governs the flow in pipe walls. When we follow other theories of plasticity which determine the start of plastic flow we find that the internal pressure for flow is only a few per cent. higher; $s_t - s_r = s_0$ is the correct law and the safest. It leads to the formula for calculating the walls of pipes:

$$P = S \log_e \frac{d_1}{d_2},$$

where P = pressure in pipe, S = admissible stress, d_1 = outside diameter, and d_2 = inside diameter. It is only necessary to determine $\log_e \frac{d_1}{d_2} = \frac{P}{S}$ once for all the pipes of a system.

This formula was first given in ENGINEERING, vol. 93, page 22 (1912), and then in my book *Plasticity in Engineering* (1947, page 10). It is now more widely accepted (see, for example, the German Entwurf D.I.N. 2413, July, 1952, "Stahlröhre, Berechnung der Wanddicke gegen Innendruck," page 9, line 21).

When the formula $\frac{P}{S} = \log_e \frac{d_1}{d_2}$ is developed into a progression $\left[\text{since } d_1 = d_2\left(1 + \frac{2\,t}{d_2}\right)\right]$ it becomes:

$$\frac{P}{S} = \frac{2\,t}{d_2} - \frac{4\,t^2}{2\,d_2^2} + \frac{8\,t^3}{3\,d_2^3} - \frac{16\,t^4}{4\,d_2^4} + \frac{32\,t^5}{5\,d_2^5} \cdots$$

It is clear that the formula for thin-walled pipes only takes into account the first term of the progression.

On page 550 of Dr. Blair's article the formula $t = \frac{P\,D}{2\,(S + P)}$ is given as the thin-cylinder formula. Compare this with the formula $S = \frac{P\,D}{2\,t}$ given on page 549. It is clear that Dr. Blair accepts the same law for plastic flow as I do, namely, $P + S = -s_r + s_t = s_0$. The complete theory gives $P = S \log_e \frac{d_1}{d_2}$, which is the correct formula. When s_0 reaches the yield point the pipe flows. D is the outside not the inside diameter. This gives a sufficient degree of accuracy and allows the accurate logarithmical formula to be replaced by $t = \frac{P\,D}{2\,(S + P)}$. But it remains an approximation.

Yours faithfully,
F. VAN ITERSON.

's Gravenhage,
Waalsdorperweg 108,
November 15, 1953.

TO THE EDITOR OF ENGINEERING.

SIR,—I am pleased to see that Dr. van Iterson has commented on my article. I am not quite clear, however, regarding the second paragraph of his letter, in which he states "As soon as creep starts there is no tendency for the hoop stress to equalise itself." Just before creep starts the stresses are not equal, but as soon as creep does start, equalisation also starts. Equalisation is not completed, however, for some time, and takes place as the result of plastic flow, as mentioned by Dr. van Iterson.

His formula appears to be based on the assumption that a combined stress has to be taken into account during creep, this combined stress being the maximum stress-difference. This theory is not universally accepted, and in any case it is difficult to see why stresses combined by elastic methods should be applicable to plastic conditions. In any case, Dr. van Iterson points out in his last paragraph that the thin-cylinder formula may be considered as a sufficiently accurate first approximation for practical use.

There seems to be some slight confusion over the formulæ on pages 549 and 550. The two formulæ $S + P = \frac{P\,D}{2\,t}$ and $S = \frac{P\,d}{2\,t}$, are, in fact, identical; but $S = \frac{P\,D}{2\,t}$ is Barlow's formula and gives a different result.

Yours faithfully,
J. S. BLAIR,
Manager, Engineering Research.
Stewarts and Lloyds, Limited,
Corby,
Northants.
November 24, 1953.

SOIL-CEMENT AND CONCRETE ROADS.

(*Concluded from page* 682.)

As reported on page 681, *ante*, the Pavings Development Group of the Cement and Concrete Association held an all-day symposium at the Institution of Civil Engineers on Thursday, November 19, to discuss the problems met in the construction of soil-cement and concrete roads. The properties of soil-cement and its value as a constructional material were discussed during the morning session and in the afternoon three papers dealing with various aspects of concrete-road construction were presented.

Concrete-Road Construction.

The first paper in the afternoon session was presented by Dr. A. R. Collins, M.B.E., director of research, Cement and Concrete Association, who reviewed the progress made in recent years in the construction of concrete roads. He pointed out that, owing to the almost complete absence of new main-road construction, practice was virtually in the state in which it stood in 1939 when mechanical methods of road laying were first introduced. Research had been continuing, however, and a great deal of experience had been acquired during the construction of airfields; knowledge, in fact, was substantially in advance of construction technique as last practised. When major road construction was resumed, the first task of the engineers concerned would be to consolidate this newly-acquired knowledge into production practice.

The problem of selecting an appropriate slab thickness was best solved by reference to the behaviour of existing examples of road construction, attempts to gain a theoretical assessment of the load capacity of pavements having been largely unsuccessful due to the number of variables involved. The most important single investigation on slab behaviour in the United Kingdom was made on the experimental road at Oxton, Nottinghamshire, where series of plain and reinforced slabs of varying thickness were laid on differing thicknesses of a soil-cement base above a uniform subgrade of gravelly sand. The value of the investigation was enhanced by including such thin slabs that failure inevitably occurred rapidly; the full value would be gained when the experiment could be repeated on different subgrades. After five years' service, the most important observation was that plain slabs less than 6 in. in thickness had failed but that 3-in. and 4-in. thick reinforced slabs though cracked, were still serviceable. Furthermore, under the particular conditions existing at Oxton, the presence or absence of the soil-cement base did not materially affect the extent of the cracking. About 12 lb. of steel reinforcement per square yard of slab appeared to be an economical quantity, giving adequate protection against cracking and permitting the expansion and contraction joints to be spaced at reasonable intervals.

In considering the problems of riding qualities of concrete roads it was noted that little experience of value had been gained during the construction of the airfield slabs. To obtain the required standards it was of paramount importance that the formwork should be fixed rigidly. Though specifications usually contained clauses to this effect, general experience showed that they were not always enforced. Furthermore, with the stiff concretes normally used in this country, it would seem essential to employ heavier compacting and grading machines than had been used previously, so that the fixing of the forms would assume even greater importance. Experimental work had shown that concrete was more effectively compacted by machines having a large amplitude of movement rather than a high acceleration, and preferably operating at about 1,500 r.p.m.

The type of surface finish required on roads was the subject of a number of conflicting requirements. Though there was in fact little difference in skidding resistance between surfaces of fine and coarse texture, there was the psychological factor that the fine texture might not appear so safe to the motorist. On the other hand, fine-textured surfaces caused much less tyre noise, which, with open-textured surfaces, could be very objectionable. Colour and texture were also affected by the illumination of the road, the lighter, finer texture being preferable where the lighting was good; on unlighted roads, with little traffic, the darker, coarse surface was preferable. On the question of colour, concrete had the advantage over other road-surfacing materials that it could be made economically with a range of colours from near white to almost black. A rough texture could be obtained by embedding a coarse aggregate into the surface but experience has shown that it is difficult to do this without lowering the riding quality of the road.

For carrying medium-weight traffic, concrete roads could easily be constructed that would require little or no maintenance, so long as there was no gross error in design or workmanship resulting in a poor subgrade which allowed uneven settlement or very poor concrete was employed. A 5-in. thick slab, reinforced with, say, 5 or 6 lb. of steel per square yard, textured and coloured according to situation and constructed much as in the past would appear to be adequate. For major traffic roads, construction would differ from that used hitherto primarily in the treatment of the sub-grade and the use of a sub-base of soil-cement. The slab itself would be 8 in. to 10 in. thick and should be reinforced with about 10 lb. of steel per square yard, preferably divided into two layers of equal weight, one near the bottom and one near the top of the slab. Such a weight of reinforcement would appear to be suitable for a joint-spacing of up to 100 ft.; with greater lengths, up to, say, 200 ft., it would appear desirable to increase the steel to 15 lb. per square yard. For jointing bars, it was suggested that stainless steel might be used in place of mild steel; the increase in capital charges involved would be large compared with the cost of the road.

German Motor Roads.

The second paper of the session was a review by Dr. Ing. E. W. Goerner, secretary of the German Road Research Association, of the lessons learned during the last 15 years from a study of the German Autobahnen. Apart from all the other advantages, it could be shown that the accident rate on the motor roads was only 40 per cent. of that experienced on all other roads. In general, the standards adopted for alignment and gradient had been found to be generally acceptable though, with the increase in heavy fast-moving freight traffic, it was probably desirable to ease the permitted maximum gradients. It was, of course, desirable that the width of the centre grass strip should be increased and the road widened at corners so as to reduce the effects of the glare of headlights, but both these factors had to be assessed in terms of the cost of acquiring additional land. The thickness of slab adopted in 1934, between 9 and 10 in., was to be used in the future in spite of the heavier loads to be carried. For future work, greater attention would be paid to the formation and sub-base.

Note had been made of failures at the road joints attributable to corroded steel dowels and efforts were being made to find improved methods. On the earlier motor roads the spacing of joints varied between 33 and 50 ft., but test sections had now been laid 500 ft. or more in length without joints, including three sections, each of 1,390 ft., reinforced with between 22 lb. and 34 lb. of steel per square yard. In general, such heavily reinforced roads have not been successful, the concrete showing too many cracks which had to be filled with a sealing compound. Furthermore, fewer cracks have been found in the thinner slabs and this has been attributed to the existence of smaller differential temperature stresses.

A close check on the surface of the concrete had shown that the original texture was still well preserved. Where deterioration had occurred, it could be traced to the use of salt employed for removing ice and show; the action of the salt was to break open the thin cement layer and the frost then loosened the aggregates in the concrete. For future work, it was proposed that air-entraining agents should be added in a sufficient quantity to produce a total pore volume of from 3 to 4 per cent. Where concrete has spalled on earlier work, it has been the practice to apply a layer of a bituminous mixture; recently, however, some repairs have been made using gunite.

For the most recent construction work, the concrete had been placed in two separate layers. The lower layer, 7 in. thick, was compacted by employing poker vibrators operating at 9,000 oscillations per minute. A reinforcement mat weighing 3·6 lb. per square yard was placed between the two layers. The top 2 in. of concrete was made with a water/cement ratio of 0·45, workability being kept adequate by including an air-entraining agent. To darken the concrete, black oxide of iron has been added in the proportion of 2 per cent. of the cement weight. Expansion joints had been formed at every 100 ft. and the joints dowelled with bars 22 mm. in diameter.

Economics of Concrete Roads.

In the final paper, entitled "Some Aspects of the Economics of Concrete Roads," by Mr. P. H. T. Gooding, an attempt was made to investigate the first costs, speed of construction, maintenance costs and the life of concrete roads. The evidence on which the survey was based had been obtained from a number of county-borough and county-council road authorities, and the whole of the evidence was given in the paper in the form of an appendix.

Of the two most recent contracts quoted, one was for housing-estate roads in a south-coast town and the other for roads for the Crawley Development Corporation. The estate roads, of which nearly 15,000 sq. yd. of lightly reinforced concrete were laid above 3 in. of ashes, cost 15*s.* 1½*d.* per square yard, exclusive of the cost of the steel. At Crawley, an 8-in. slab, reinforced with 7 lb. of steel per square yard and laid on 4 in. of lean concrete, was to be placed for a contract price of 38*s.* per square yard.

For the speed of construction, various estimates indicated that, for a main motorway, 24 ft. wide, and working an 8-hour day, an 8-in. top course could be laid at the rate of at least 1,450 sq. yd. a day (i.e., about 180 linear yards of road a day). American estimates of the life of concrete roads were between 23 and 28 years, and of observed roads in the United Kingdom, 48 per cent. were 20 years and older and 13 per cent. were 25 years old or more; all were still in commission. No figure for age was quoted for any road known to have been broken up where it had ceased to be serviceable. The average maintenance cost given by various road authorities was 0·65*d.* per square yard per annum; of the sample figures included in the make-up of this average, a number were rough estimates and no account had been taken of maintenance costs which had been described by the authority concerned as negligible.

The records showed that, of the concrete roads laid in the United Kingdom, about 83 per cent. were reinforced, and a comparison of costs and of expected life showed that the use of reinforcement was economically sound. Sufficient evidence was not available to assess the economic values of prestressing the concrete, the object of which was to reduce the number of joints by increasing the permitted length of slab. Similarly, further experience was required of the mechanical laying of coarse-textured surfaces before the economic value of such processing could be assessed.

Summarising the evidence collected from both the United Kingdom and the United States, it appeared that the minimum life of a concrete road carrying heavy traffic was 20 years and that of housing-estate roads 30 years; the annual cost of maintenance in each case did not exceed a penny per square yard.

Electric Motor and Control Gear Manufacture.—The *L.S.E. Engineering Bulletin* for November, which is published by Laurence, Scott and Electromotors, Ltd., Norwich, has been produced with the object of outlining the range of that company's manufactures and of describing the various purposes for which they are used, on the occasion of the firm's 70th anniversary. The contents include well-illustrated descriptions of interesting equipments and the result is almost a text-book of activities in an important field. It is felt that the issue may be of particular interest to students, and for that reason copies have been reserved for the use of lecturers in engineering colleges.

THE IRON AND STEEL INSTITUTE.

THE autumn general meeting of the Iron and Steel Institute opened in London on the afternoon of Tuesday, November 24. A "Symposium on Sinter" was commenced after the general meeting in the afternoon of November 25 and was concluded on Thursday, November 26. In the absence of the President, Mr. James Mitchell, C.B.E., Mr. Richard Mather, a past-President, took the chair at the general meeting. He proposed, on behalf of the Council, that the Hon. R. G. Lyttelton, a vice-president, be elected President, to take office at the annual general meeting in 1954 and to serve for one year. This was agreed to unanimously and with acclamation. Among other announcements, Mr. Mather stated that the Council had availed themselves of a recent opportunity to renew the lease on the headquarters of the Institute, at 4, Grosvenor-gardens, London, S.W.1, for a period of 60 years. The old lease had only some two years to run. He thanked the many firms in the industry who by their subscriptions had made this step possible. Mr. Mather also confirmed that the invitation of Jernkontoret, Stockholm, to hold a special summer meeting in Sweden had been accepted and that the meeting would take place from June 5 to 18, 1954.

CHANGES IN THE COUNCIL.

The secretary then announced the changes in the Council which had taken place since the previous general meeting held in April, 1953. Mr. A. H. Ingen Housz had been elected an honorary vice-president and Mr. C. H. T. Williams a member of Council. Several honorary members of Council had been elected to serve during their periods of office in other institutions. They were Mr. A. W. Ellis, President of the Ebbw Vale Metallurgical Society, in place of Mr. W. D. Jenkins; Mr. H. D. Ward, President of the Leeds Metallurgical Society, in place of Dr. N. J. Petch; Mr. H. J. Miller, President of the Liverpool Metallurgical Society, in place of Mr. R. S. Brown (who, however, remained a member of Council in another capacity); and Mr. D. L. Blewett, President of the Swansea and District Metallurgical Society, in place of Mr. H. N. Bowen.

In addition to the above, three vice-presidents and five members of Council were due to retire at the next annual general meeting but were eligible for re-election. The vice-presidents were Mr. N. H. Rollason, Sir Charles Bruce-Gardner, Bt., and Mr. C. R. Wheeler, C.B.E. The members of Council were Mr. H. Boot, Mr. S. Thomson, Mr. E. T. Judge, Mr. E. J. Pode and Mr. B. Chetwynd Talbot.

ANDREW CARNEGIE SCHOLARSHIPS.

Since the last general meeting three awards of Andrew Carnegie scholarships had been made, namely, 100*l.* to Mr. S. W. K. Shaw, of Sheffield University, to assist research on carbide formation in chromium-vanadium steels; 100*l.* to Mr. J. Wilcock, of Liverpool University, to assist research on the influence of sulphur and manganese on the graphitisation of the iron-carbon-silicon system; and 50*l.* to Mr. S. V. Radcliffe, also of Liverpool University, to assist research on the isothermal transformation of austenite.

The secretary's final announcement was that all the affiliated societies of the Institute had now been made kindred societies, according to by-law 21. The effect of this was that, as from January 1, 1954, members of these societies who were not already members of the Institute or of the Institute of Metals could become members at reduced rates.

FLAME LENGTH IN OPEN-HEARTH FURNACES.

At the conclusion of the formal business of the general meeting some papers were presented and discussed. The first three all dealt with emissivity, flame radiation and heat transfer in the open-hearth furnace and were discussed jointly. The first was entitled "The Effect of Emissivity and Flame Length on Heat Transfer in the Open-Hearth Furnace" and was by Professor M. W. Thring. It was a contribution from the Steel Practice Committee of the Steelmaking Division of the British Iron and Steel Research Association. The author stated that recent developments in port design and the aerodynamics of flames had been taken into account in calculating the optimum flame for the open-hearth furnace. This had been done by postulating a simplified furnace and flame, and calculating in detail the temperatures along the flame and the roof. The fuel was assumed to be oil with a net calorific value of 9,880 C.H.U. per lb. atomised with ½ lb. of steam per pound of oil. Four types of flame had been considered, each for three different fuel-input rates, and the comparison indicated the optimum flames for three distinct phases of the open-hearth process, namely, charging, melting, and refining. During charging, in practice, the choice usually lay between rapid combustion with a falling emissivity or slow combustion with a maintained emissivity. A long flame with maintained high emissivity gave a more rapid heat input to the steel for a given fuel-input than rapid combustion with falling emissivity. If rapidity of melting were the primary consideration, the delayed-combustion flame with maintained emissivity was the best type of flame for the melting-down period. It should be followed by rapid combustion with low emissivity, each consuming oil fuel at the rate of 4,000 lb. per hour. If minimum fuel consumption were the primary consideration, rapid combustion with 2,000 lb. per hour gave the best results. The refining period might be taken as when the purpose of the flame was not to supply an appreciable amount of heat to the bath, but simply to maintain the bath temperature. The best flame was therefore that which gave the flame temperature above 1,500 deg. C., in all except the first zone, with the lowest fuel-input rate.

The second paper, also a contribution from the Steel Practice Committee, was by Mr. W. P. Cashmore and Professor M. W. Thring and dealt with "Experiments on Flame Radiation in an Empty Open-Hearth Furnace." The authors stated that to find the effect of changing the flame conditions on the radiation along the flame in an oil-fired open-hearth furnace, a series of eight flames had been studied in an empty 100-ton furnace maintained in as steady a state as possible. It had been found that steam quality had a large effect, the overall radiation being 7 per cent. higher when slightly superheated steam was used for atomisation than when 0·85 dry steam was used. Colder oil with higher steam quantity and hotter oil with lower steam quantity gave 6 per cent. more radiation than the reverse conditions, implying that the optimum steam-oil ratio rose when the oil viscosity increased. A comparison with recently obtained results at Ijmuiden on oil flames with cold air showed that air preheat of 1,000 deg. C. doubled the peak radiation, owing to an effective increase in flame temperature at this point from 1,200 deg. C. (cold air) to 1,600 deg. C. (preheated air).

The third paper, entitled "The Length of Oil and Gas Flames," by Mr. A. L. Cude, was put forward by the Fuel Committee of the Plant Engineering Division of B.I.S.R.A. The author stated that equations defining the length of non-swirling jet flames had been derived from the theory of turbulent jets and confirmed by experiment over a wide range of conditions for gas-oil and town gas. Experiment had shown that similar equations could be applied to swirling jets. Values of the empirical coefficient in the equations as found in the laboratory could be expected to differ from those applicable to industrial conditions, but the relative effects of changing operating variables could be summarised as shown in Table I. The definition of "jet fluid" was that part of the total flow which was the source of the momentum flux controlling the mixing process. With low values (up to 8 lb. per lb.) of the jet-fluid : fuel ratio, there was little difference between swirling and straight jets, but when the jet fluid exceeded about 80 per cent. of the theoretical combustion air, swirl caused a large reduction of flame length. At higher air : fuel ratios (greater than 8 lb. per lb.) the swirling air stream had a pronounced back-flow, which stabilised the flame at velocities that would cause blow-off with non-swirling air. To obtain the maximum effect of swirling secondary air, the fuel jet should be such that the fuel was immediately carried into the main air stream. A high-velocity narrow-angle fuel jet flowed down the central core and poor mixing resulted.

TABLE I.

Variable Changed.	Effect on Flame Length.
Jet-fluid : fuel ratio increased	Decrease.
Jet-fluid and fuel changed in same proportion	No change.
Velocity increased by change of burner size ..	Decrease.
Jet-fluid temperature increased	Decrease.
Flame temperature increased	Increase.

(*To be continued.*)

INAUGURATION OF THE WATER RESEARCH ASSOCIATION.

THE new Water Research Association was incorporated under the Companies Act, 1948, on November 19, and held its inaugural conference under the chairmanship of Sir William F. Neill, F.R.I.C.S., J.P., chairman of the board of governors, at Church House, Westminster, on the following day.

The water-supply industry is estimated to be worth 600*l.* million, three-quarters of which sum is estimated to be the value of the piping and distribution systems buried underground; and, with the health of the population being largely dependent on the purity of water supplies, the establishment of such a research organisation for the industry as a whole seems to be a matter which has long become overdue. The Water Research Association commenced with the appointment, under Sir Roger Hetherington, of a sub-committee of the British Waterworks Association to investigate and report on the organisation of research. The report of the sub-committee was presented at the annual general meeting of the British Waterworks Association held on June 28, 1950, and from that date onwards negotiations with members and the Government departments concerned have been proceeding. The Department of Industrial and Scientific Research expressed the view that, having regard to the size of the water-supply industry, it was necessary for the scope of the research organisation to be sufficiently wide and for commensurate funds to be forthcoming from members over a minimum period of five years. The constitution of the Association therefore provides for an annual subscription from members assessed at the rate of one shilling for each hundred pounds of water revenue, but limited to 2,000 guineas as a maximum and to 25 guineas as a minimum. It is also estimated that the sum which can be usefully expended on research will increase from 6,000*l.* to 21,000*l.* a year, over the next five years.

In opening the inaugural conference, Sir William F. Neill said that no good purpose would be served by outlining the long history of tedious negotiations, but he hoped that in due course the Research Association would become equal in stature to its parent association, the British Waterworks Association. Continuing, he said there had been practically no concerted research in the water industry since its development, and he drew attention to the necessity of protecting underground piping from internal and external corrosion, and also to the need for apparatus which would locate the sources of leakages and indicate the quantities of water lost.

The address was supported by the Rt. Hon. the Viscount Falmouth, M.I.Mech.E., who said that the establishment of a water research organisation was overdue and that such an organisation ought to have been brought into being long ago. He referred to the possible pollution of water by radio-active products as one of the problems requiring attention.

Mr. G. M. McNaughton, C.B., M.I.C.E., representing the Minister of Housing and Local Government, said that the industry had been able to supply cheap water in the past owing to conveniently-situated gathering grounds or adequate underground sources of supply. The position, however, was now changing, as pollution increased with the increase in industrial processes, and underground water supplies were being depleted.

THE WEAR OF CARBON BRUSHES AT HIGH ALTITUDES.*

By R. F. SIMS.

THE carbon brush has been in general use on electrical machinery for so long that the properties which determined its selection tend to be forgotten. Briefly, they are a low coefficient of friction combined with a low contact resistance; and it is this unique combination of properties which has resulted in the almost universal adoption of carbon as a current collector from commutators and slip rings. If the rate of wear of a brush on a commutator is compared with that on a slip ring in normal atmospheric conditions, it is found that the former is very much higher than the latter, suggesting that the electrical wear due to commutation is more important than the mechanical. On the highly-rated generators used on aircraft the normal rates of wear lie between 0·0001 and 0·001 in. per hour. If, however, such generators (particularly if they are cooled by air blast) are flown to a height of about 30,000 ft., the rate of wear is liable to rise suddenly to 0·01 or 0·02 in. per minute; the rubbing surface of the brush becomes rough and disoriented and the surface of the commutator is slightly greyed by a deposit of graphite. The commutator or slip ring is also worn rapidly at a rate which appears to be entirely independent of the current flowing across the contact surface. It therefore seems fair to conclude that the phenomenon is mechanical rather than electrical.

It is immediately apparent that Sir William Bragg's conception of graphite as a substance of inherently low friction on account of its crystal structure is no longer completely satisfactory and that atmospheric conditions are an essential factor in the process. Savage recognised that the abnormally high rates of carbon wear, which occur at high altitudes and sometimes in very cold dry weather on the ground, are due to the absence of the adsorbed films which in normal atmospheric conditions are sufficient to prevent the cohesion of the brush to the commutator. Savage and van Brunt have also shown that whenever carbon is rubbed on a metal a film of carbon is laid down on the latter. Consequently, when a brush bears on a commutator rubbing takes place between carbon and carbon, and it is in the effect of the atmosphere on the carbon that an explanation of high altitude wear must be sought. Moreover, Savage found that he was able to induce rapid wear, accompanied by very high friction, in a vacuum chamber by freezing out all the water; and that there was a critical water-vapour pressure of about 3 mm. of mercury below which rapid wear occurred. This critical pressure is not attained above 12,000 ft. on the wettest days, and on dry days not above sea level.

Apparatus has been developed at the Royal Aircraft Establishment to study these phenomena and consists essentially of a group of three sealed chambers containing slip rings, which are driven by external motors and brushes can be applied on the rings. Air, which has been dried to the desired frost point, is drawn from two refrigerators through each chamber by a vacuum pump. The brush temperature can be maintained at any desired value by thermostatically-controlled thermocouples. The frost point may be varied by mixing in suitable proportions the air taken from the two refrigerators, one of which works at from — 50 deg. to — 70 deg. C. and the other at 0 deg. C.

An investigation on electro-graphitic brushes at 130 deg. C. under different conditions of altitude and humidity showed that at a given altitude the rate of wear falls rapidly to a negligible amount at a fairly sharply defined value as the vapour pressure rises. At a given vapour pressure the rate of wear is greater for a smaller total pressure, that is, at a greater altitude. It would appear that the effects of water vapour and total atmospheric pressure are complementary, and that the phenomenon, which has been called "high altitude" wear, can occur at altitudes below 10,000 ft. In fact, it rarely, if ever, is experienced below 20,000 ft. If rapid wear is taking place and the altitude is reduced there comes a point where rapid wear stops suddenly. For convenience this is called the critical altitude for the brush under the particular conditions. If a brush is running normally below the critical altitude and the altitude is increased rapid wear will not normally occur when the critical altitude is reached, but at some higher value. This last value depends on a number of factors, the most important of which is the length of time the brush has been running in a moist low altitude. It is common experience that a healthy commutator carries a uniform brown skin and it can be shown that it is in this skin that the temporary immunity from wear resides. The skin consists of a layer of cuprous oxide adjacent to the copper and a second layer of graphite and ash. A layer of cuprous oxide alone, formed by heating, does not provide this immunity.

The critical altitude or pressure is found to vary considerably with the temperature, while the partial pressure of water vapour varies with the altitude. This is consistent with the hypothesis that normal lubrication depends on a mono-molecular film of water. The maintenance of such a film depends on a balance between the rate of adsorption, which is a function of the pressure, and the rate of evaporation, which is a function of the temperature. As the temperature rises so does the minimum vapour pressure necessary to prevent rapid wear.

Organic adjuvants are effective so long as the temperature is low and the brushes are not required to carry current, but at high temperatures and with the extremely severe conditions which must obtain locally on the contact surface they are rapidly driven off or broken down. Over the limited range where they are effective they presumably work in the same manner as water by saturating the surface faces of the graphite. There are at least two schools of thought about the action of inorganic adjuvants of which the most successful are the metallic halides, such as barium fluoride. One holds that they act as catalysts promoting the oxidation of the copper surface and the other considers that they act in the same manner as water by saturating the surface forces. If the critical-pressure curves for brushes treated with such materials are examined it is found that they are little, if any, better than untreated brushes at the lower temperatures. At the higher temperatures, on the other hand, they are much better, a result which would be in accordance with both schools of thought just mentioned.

If adjuvant brushes are applied to a clean commutator and immediately exposed to high-altitude conditions they will behave no better than untreated brushes. They will, however, run indefinitely at high temperatures and high atmospheric pressure and humidity, whereas untreated brushes will begin dusting within a short time of exposing them to such conditions. It appears once more that the protection conferred by low-altitude running is due to the development of a film on the commutator surface. Indeed, when a satisfactory film has been formed it is possible to replace adjuvant by untreated brushes and to continue running for long periods at high altitudes without dusting. Barium fluoride is completely ineffective on a silver ring which would appear to demonstrate that film formation is a chemical process, although, in view of the ineffectiveness of a simple oxide film on copper, it would seem that the role of the adjuvant is not merely that of an oxidation catalyst. It has been confirmed by experiment that the protective film built up by barium fluoride brushes is destroyed by sparking if the altitude is above the critical value for the conditions.

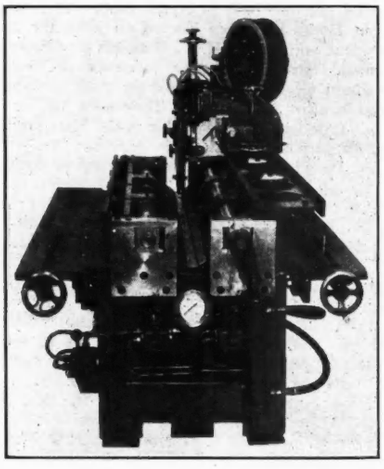
In the application of adjuvant brushes to practical machines a temperature of 170 deg. C. is required for the formation of a satisfactory film and, in order to sustain such a temperature, the commutator risers must be hard-soldered to the armature conductors. On the other hand, under ground-level conditions, the temperature rise of an adjuvant brush is frequently considerably higher than that of an untreated brush on the same machine, chiefly owing to the greater electrical losses. Adjuvants also have a serious effect on what are called "the collecting properties of the brush," by which is meant the ability to maintain an even distribution of current over its surface.

There are lessons for the generator designer in these results. He should never employ treated brushes unless they are really necessary because the generator is required for high-altitude aircraft. He must make conditions as easy as possible for the brushes. Sparking must be avoided by the use of full armature compensation and interpoles, by correct proportioning of the magnetic circuit to avoid the necessity for critical brush setting, by rigid and accurate commutators and by stable brush-box design. Allowance must be made for the greater temperature rise to be expected and the characteristics of both untreated and adjuvant brushes should be taken into consideration from the outset.

* Paper read before the Utilisation Section of the Institution of Electrical Engineers on Thursday, November 19. Abridged.

CLAMPING MACHINE FOR STRIP WELDING.

THE accompanying illustration shows a machine designed by F. Bode and Son, Limited, Buxton-road, Leek, Staffordshire, to enable short lengths of strip material to be welded together into a long coil and thus permit continuous cold rolling to be carried out. It consists of a table on which two clamping beams are mounted, one on each side as shown in the illustration. These beams can be moved vertically in guides, power for this purpose being provided by two pneumatic or hydraulic rams,



which operate through a shaft. This shaft can turn through 135 deg. and, as it rotates, it drives an eccentric which raises the clamping beam vertically. The butt welding of lengths of strip is effected by an Argonarc automatic head which is mounted on a track formed by a machined rolled-steel joist. This track is fixed to the clamping beam on the right of the illustration, and therefore moves with it. The other clamping beam is provided with a hinged bar which can be lowered to form a stop. The material to be welded is fed against this stop so that its edge is exactly on the centre line and it can be turned back after setting. In addition, the material is centralised by two sets of pegs which move in slots running parallel to the clamping beams and are operated by a handwheel through right-hand and left-hand screws. The toes of the clamping beams are shaped so as to give easy access to the welding torch and a backing strip, which is flush with the table top, is fitted between them. This strip can be made of different materials depending on the metal that is being dealt with. A small groove of parabolic section is provided so as to form the weld into a suitable shape for cold rolling.

The machine is made in two sizes one of which can accommodate strip from 9 in. wide upwards, while a smaller, and rather simpler, design is available for widths of from 4 in. to 18 in. The larger machine can be fitted with a self-contained electrically-driven pump, while the smaller size can be operated by hand.

COAL STORAGE AT HACKNEY POWER STATION.

PREVENTION OF SPONTANEOUS COMBUSTION IN COAL STOCKS.

THE coal used in the high-pressure boilers at the Hackney power station of the British Electricity Authority is delivered by William Cory and Son, Limited, in barges of 125-ton capacity at the rate of 2,900 tons per week throughout the year. It is unloaded by two overhead telpher cranes which discharge either into the bunkers or on to a stock-pile. During the summer, when only two of the five boilers, each of which has an output of 150,000 lb. of steam per hour, are being used for about 10 hours per day, the coal consumption is about 980 tons per week, leaving a surplus of some 1,900 tons per week for stockpiling and consumption during the winter months when the deliveries are insufficient to keep pace with requirements. The stockpile consists of three bays in which 26,000 tons of coal can be stored to a depth of 12 ft. over a total area of 10,000 sq. ft. This year, however, owing to large-scale building operations connected with the extension of the station, only 6,500 sq. ft. is available, on which coal has been piled to a depth of 20 ft. Under these conditions there is considerable risk of spontaneous combustion, to prevent which the coal is compacted by a crawler tractor, which is illustrated in the accompanying photograph, and is equipped with a hydraulic angle dozer manufactured by Mackay Industrial Equipment, Limited, Feltham, Middlesex.

The operating procedure is for coal to be dropped from the crane, which extends over the stockpile at a height of 90 ft., into the two available bays on alternate days. The coal deposited during one day is compacted by the angle dozer on the next day to form a layer about 6 in. deep, an advantage being that the right degree of compression is obtained owing to the wide tracks and low ground pressure of the machine. In fact, a satisfactory compromise has been reached between more solid compaction, which would prevent the cranes penetrating sufficiently into the pile to recover a full load, and too loose compaction, which would give rise to the risk of spontaneous combustion. The machine requires only one operator and has rarely to work more than 8 hours a day. With the drag scraper which was previously employed not only were fires frequent, owing to the interstices of the pile containing air, but two men were required to operate it and it was necessary for it to work for 24 hours a day to keep pace with the deliveries.

It is estimated that the angle dozer can move 3 cubic yards per pass and during the 26 weeks it has been in use it has dealt with 16,000 tons in 400 hours. It should therefore be capable, during the winter, of feeding sufficient coal back from the stockpile into the bunkers at the rate of 1,300 to 2,400 tons per week and thus supplying the five boilers which are then steaming for 18 to 20 hours a day.

THE BUILDING EXHIBITION AT OLYMPIA.

(*Concluded from page* 653.)

A NOTICEABLE feature of this year's Building Exhibition was the large number of stands given over to Government Departments and the several research and development associations. The stands of the individual firms and companies were filled with equipment and products—some new, and on display for the first time, some old, well tried, and having the backing of a proved reputation—but the visitors to the Exhibition paid greatest attention to the displays and demonstrations illustrating modern developments in processes rather than to equipment as such.

CEMENT AND CONCRETE ASSOCIATION.

The display of prestressed concrete sponsored by the Prestressed Development Group of the Cement and Concrete Association, 52, Grosvenor-gardens, London, S.W.1, occupied the whole of the east end of the gallery of the National Hall. Four times a day, demonstrations of prestressing by each of the Freyssinet, Lee-McCall and Magnel-Blaton systems were given to a large and interested audience. There was also a comprehensive display of pre-cast prestressed products, particularly flooring units, but also including examples of fencing posts, lamp-standards and pipes. The stand of the Cement and Concrete Association itself was devoted to displaying concrete blocks. Samples of different types of concrete block and of different surface treatments were to be seen, including blocks suitable for load-bearing and non-load-bearing walls and partitions, for backing other facing materials or for the wall facings themselves. Examples were shown of attractive surface finishes, suitable for both external and internal facings, involving exposed-aggregate finishes, which were obtained on the concrete blocks by brushing, spraying or etching with acid. The display also included blocks of a lightweight concrete which possesses the property of high thermal insulation.

DEPARTMENT OF INDUSTRIAL AND SCIENTIFIC RESEARCH.

Two establishments of the Department of Scientific and Industrial Research had stands at the Exhibition. The Joint Fire Research Organisation, Boreham Wood, Elstree, Herts., carries out a wide range of experimental work on the causes of fires, the behaviour of buildings in the event of fire, and fire-prevention problems, and the exhibits on this stand illustrated some of the work at present in hand. For example, there were on view the small-scale models used for the study of the phenomenon of flamespread and for examining methods for minimising the spread of fires in buildings. Also on view was a large-scale test rig of the type used to investigate the fire resistance of slabs of reinforced and prestressed concrete, the load being applied uniformly to the top of the slab by jacks operating against an overhead steel joist, the fire being applied to the underside of the slab.

The work of the Building Research Station, Garston, was illustrated by a display of samples, models and photographs. Working in collaboration with the Ballast, Sand and Allied Trades' Association, a survey has been made of the sands to be found in the United Kingdom, and samples were to be seen among the exhibits. The survey has shown that the finer sands predominated and, furthermore, that the coarser sands were not readily available in many parts of the country. The sands have now been classified into four zones and research has shown that good quality concrete could be made from each of the sands, provided that the proportions of the mix were suitably adjusted.

The Station has shown that good bricks, examples of which were displayed, could be made from mixtures of clay and pulverised-fuel ash, the ash content sometimes amounting to nearly 90 per cent. About 2,000,000 tons of such ash are being produced annually at power stations, and the quantity is likely to increase; disposal of the ash is troublesome and its use for making bricks may provide an outlet for it. Its addition to the clay offers possibilities of reduced costs for both raw materials and fuel, combined with increased production because of the saving in drying time that is gained. Another part of the display illustrated by photographs the full-scale experiment, made in co-operation with the City Engineer, Norwich, to demonstrate the value of a small rail-mounted tower crane on a small compact house-building contract. In that instance, 32 houses were completed externally in 132 days with a saving in labour costs of about 100 per cent. per house.

TIMBER DEVELOPMENT ASSOCIATION.

The exhibit of the Timber Development Association, 21, College-hill, London, E.C.4, was all the more interesting for the recent announcement that all controls on the consumption of softwood, hardwood, plywood and veneers had been abolished. The exhibition stand was displayed under a framework built from the T.D.A.'s new rigid timber frame, a form of construction well suited to the requirements of the village church or hall. The frame, consisting of built-up timber sections joined together by steel gusset plates, bolts and timber connectors, was shown to have marked advantages where unobstructed headroom, low maintenance costs and aesthetic considerations were important. Glued laminations have been used for the solid timber members, which might be of either hard or soft woods, and it was claimed that the frames possessed a high degree of fire resistance. Other exhibits included variations of low-pitched timber roof trusses having a wide application to such buildings as hospitals, schools, offices, assembly halls and flats. The trusses have been designed to be able to carry suspended ceilings and roof-access gangways. A design by the T.D.A. for a 25-ft. high Class "A" lighting column with a laminated cross arm was illustrated by a 4-ft. model standard in red meranti. The base of the column was shown as consisting of a reinforced-concrete stub housing which contained the switch box. As an example of the modern use of plywood, the Association exhibited a

model of a plywood grain silo which has been erected at Silsoe, Bedfordshire. The silo, easy to assemble and transport to a new site, has been subjected to rigorous field storage tests by the National Institute of Agricultural Engineering and has been declared satisfactory. It has high resistance to weather and the smooth overall finish is claimed to assist cleanliness.

Other similar bodies represented at the Exhibition included the Ministries of Works and of Housing and Local Government; the Copper Development Association, Kendals Hall, Radlet, Hertfordshire; and the British Rubber Development Board, Mark-lane, London, E.C.3. The stands of the two Ministries emphasised the problems inherent in modern planning and building and the means, particularly mechanisation, being developed to overcome the problems. The recent applications of rubber to the building and civil-engineering industries were illustrated by rubber sheet and tile floorings, wall coverings in the form of sheet rubber, latex-cement compositions, anti-vibration mountings, pipe jointings, rubber for thermal and sound insulation and rubberised bitumen for use in the construction of flexible pavements for roads. The important contribution that copper can make was illustrated by a display showing the ease with which copper sheet and strip can be shaped and jointed for service on both pitched and flat roofs, and by examples of the wide range of fittings that are available to meet the piping requirements of any type of piping installation, domestic or industrial.

CONTRACTS.

VICKERS-ARMSTRONGS LTD., AIRCRAFT DIVISION, are supplying two "V.I.P." Vickers Viscount turbo-propeller air liners to the Indian Government. One will be for the use of the President and the Prime Minister of India and the other, fitted with 40 seats, is for the use of members of the Indian Government and senior Indian officials. Both aircraft will be delivered in the summer of 1955. They will be fitted with Rolls-Royce Dart engines, which will enable the aircraft to cruise at a speed of over 330 miles an hour.

THE GENERAL ELECTRIC CO., LTD., Magnet House, Kingsway, London, W.C.2, have been awarded a contract for the installation of a new automatic announcement system at Stratford Station, on the Eastern Region line of British Railways, from Liverpool Street to the Eastern Counties. The various types of announcements are pre-selected by the signal-box staff and as a train approaches the station it operates the track circuit connected with the signalling system, which, in turn, switches on a special form of tape reproducer connected to the station loud-speaker system. The loud speakers then commence, announcing: "The train approaching No. — platform will call at . . . " As the train draws up at the platform a further signal switches the tape reproducer over to a second series of announcements: "The train standing at No. — platform will call at . . . "

THE BRITISH STRADDLE CARRIER CO., LTD., Cambridge, have received a large order from Russia for a supply of Timber Wolf self-loading machines, used for transporting long, heavy loads to or from docks and goods yards. The machine is Diesel operated and is handled by one man. It can lift an 8-ton load of 15 yards in length in five seconds and carry it at a speed of 25 m.p.h. The maximum load is 10 tons. Overseas distribution of the machine is controlled by MATERIALS HANDLING EQUIPMENT (G.B.) LTD., 7, Chesterfield-gardens, London, W.1.

THE DE HAVILLAND AIRCRAFT CO., LTD., Hatfield, Hertfordshire, have received an order for three Comet series 2 aircraft fitted with Rolls-Royce Avon engines for Canadian Pacific Airlines. They will be used initially on a trans-Pacific service linking Vancouver with Sydney. The "Comet 2" seats 44-48 passengers and is capable of travelling at a speed of nearly 500 m.p.h. It is anticipated that the aircraft will be delivered during 1954.

STEWARTS AND LLOYDS LTD. have received an order for several hundred miles of pipe for the Haines-Fairbanks pipeline project in British Columbia and Alaska. The value of the order is 1,000,000*l.*, and will be paid for in dollars. The manufacture of the pipes will be undertaken in the company's works in Glasgow, South Wales and the Midlands.

THE BRISTOL AEROPLANE CO., LTD., Filton, Bristol, are delivering to Silver City Airways Ltd., 1, Great Cumberland-place, London, W.1, three "Superfreighter" vehicle-ferry aircraft for delivery in the spring of 1954. Each aircraft can carry three motor cars and 20 passengers; it has been specially designed for the cross-Channel vehicle ferry service.

LABOUR NOTES.

IN spite of the lack of unanimity among its affiliated unions, the indications at the time of going to press were that the efforts of the Confederation of Shipbuilding and Engineering Unions to stage a 24-hour stoppage of work throughout the engineering industry last Wednesday were likely to meet with a considerable measure of success. There was no sign of intervention by the Ministry of Labour, although the Ministry's conciliation officers were stated to be in informal contact with influential representatives of both sides. Intervention by the Ministry in the dispute may well come in due course, but, to be effective, such action requires to be carefully timed. How far the strike may be successful in bringing employees in the industry nearer to an increase in wages is another matter. Not least among the immediate effects of any stoppage, however brief, is the slimness of the wage packets of those who participate.

A token strike, to last for 24 hours from the morning of last Wednesday, was approved at the special meeting of delegates from the 39 unions affiliated to the Confederation, as a protest against the outright rejection of the organisation's demand for an increase of 3*s.* in the pound in the wages of all adult male operatives in the engineering industry. The proposals were firmly supported by the Amalgamated Engineering Union, but resisted by representatives of the Transport and General Workers' Union, the National Union of General and Municipal Workers, and some of the smaller craft unions. Both the T.G.W.U. and the N.U.G.M.W. have strongly advocated the setting up of a court of inquiry into the dispute, or, alternatively, that the wage claim should be submitted to arbitration. A similar view was taken by Mr. Jack Tanner, the President of the A.E.U., who announced on November 26 that he was not in favour of the strike and that he considered that the Confederation's case should be submitted to a court of inquiry.

It was also announced on November 26 that the executive committee of the N.U.G.M.W. had decided that members of the union employed in engineering establishments and shipyards should not be called upon to take part in the stoppage. The N.U.G.M.W. stated that one of the Confederation's rules provided that no affiliated union should be requested to withdraw its members until a decision had been taken in accordance with the union's own rules and that any general movement by the unions should be submitted to a ballot vote, if necessary. Mr. Tom Williamson, the general secretary of the N.U.G.M.W., said that reports received from the union's branches indicated definite opposition to a stoppage of work, unless a ballot was taken beforehand.

In the case of the T.G.W.U., the engineering section decided to leave the decision respecting taking part in the stoppage to its local secretaries and shop stewards. It may be recalled that the Confederation's resolution only requested members of affiliated unions to confine their activities to leaving their places of employment, and that there was careful avoidance of any reference to a "strike." It was reported last Saturday that efforts were being made in some quarters to induce engineers engaged in the railway workshops to take part in the stoppage. Following reports that men employed in civil air transport had been asked to give their support, a circular was issued by Mr. J. Matthews, as secretary of the trade-union side of the National Joint Council for the industry, urging the men not to participate. He stated that the unions had always insisted that the civil air-transport industry was in no way allied to general engineering and that, up till then, they had been successful in maintaining that view.

Pleas to "stop this mischief-making" are made by Mr. Arthur Deakin, C.H., the general secretary of the T.G.W.U., in the December issue of the *Transport and General Workers' Record*, the union's official journal. He deplores attacks on the union in the national Press, by people who have "had some experience in the trade-union movement but a great deal more in the political field" and, in particular, refers to criticisms that there have been delays in disposing of wage claims. Of course, Mr. Deakin states, quite frequently there are delays in settling wage claims. There are always likely to be, whether it be in private industry or in nationalised undertakings, so long as there are two parties to negotiations. To expect, and dogmatically to assert, that the time taken to argue wage claims and examine all their implications is just a time-wasting device is without reality.

Referring to a proposal in a national Sunday newspaper by Mr. Alfred Robens, a Minister of Labour in the Labour Government, that the two sides involved in wage claims should agree to set a time limit to each stage of their negotiations, Mr. Deakin comments that this suggestion completely ignores the fact that trade unions frequently have to face a negative answer to their claims. Is it proposed, Mr. Deakin asks, that unsatisfied claims should then be referred to arbitration? If so, is the decision to be final and binding? Above all, would such a course give satisfaction to the men on whose behalf the claim was made? Alternatively, is it suggested that, every time there is a failure to agree within a limited space of time, this should automatically be followed by strike action to compel the acceptance of the claim for an increase in wages or improvement in conditions? No trade-union officer, he concludes, has a vested interest in delay.

In the United States, there was an advance in the cost of living, for all items, from 115·3 in mid-September to a new high-level record of 115·5 in mid-October. Although small, this was the fifth successive monthly increase to take place in living costs and represented an advance of 1·1 points over the level for mid-October, 1952. Since the commencement of the Korean War, the cost of living has risen by no less than 13·4 points above the average of 1947-49, on which the United States Department of Commerce official index is based.

Claims for increases in wage rates were submitted by all sections of the seamen's side at a meeting of the National Maritime Board in London on November 19. The shipowners' side of the Board undertook to give careful consideration to the new demands. Their reply will be presented at another meeting of the Board which has been arranged for December 18.

Trade unions in the United Kingdom increased the number of their members during 1952 to a total of 9,524,000 at the end of the year, thus establishing a new high record. This represented an advance of about 43,000 above the total at the end of 1951, and some 281,000 above the total at the end of 1950. Statistics compiled by the Ministry of Labour and National Service, and based largely upon information supplied by the Registrars of Friendly Societies for Great Britain and Northern Ireland, show that the number of trade unions known to have been in existence at the end of 1952 was 690, including 25 organisations with headquarters in Northern Ireland. This was a reduction of 19 on the total for 1951, and was the net result of 27 small unions being absorbed by larger bodies or otherwise ceasing to function, and of the formation of eight new unions.

Some idea of the concentration of membership strength in the hands of the larger organisations may be gained from the fact that, of the total of 690 unions existing at the close of last year, 321 unions, about 46·5 per cent. of the whole, had fewer than 500 members each. Their total members numbered only 56,000, or about 0·6 per cent. of the strength of the movement. At the other end of the scale, 33 unions, about 4·8 per cent. of the whole, had at least 50,000 members each. Their total membership numbered 7,494,000, or about 78·7 per cent. of the strength of the entire trade-union movement. At the end of 1952, the number of federations of trade unions in the United Kingdom was 49, the same as at the end of 1951.

COMBINATION MECHANICAL STOKER.

HOPE'S HEATING AND ENGINEERING, LTD., BIRMINGHAM.

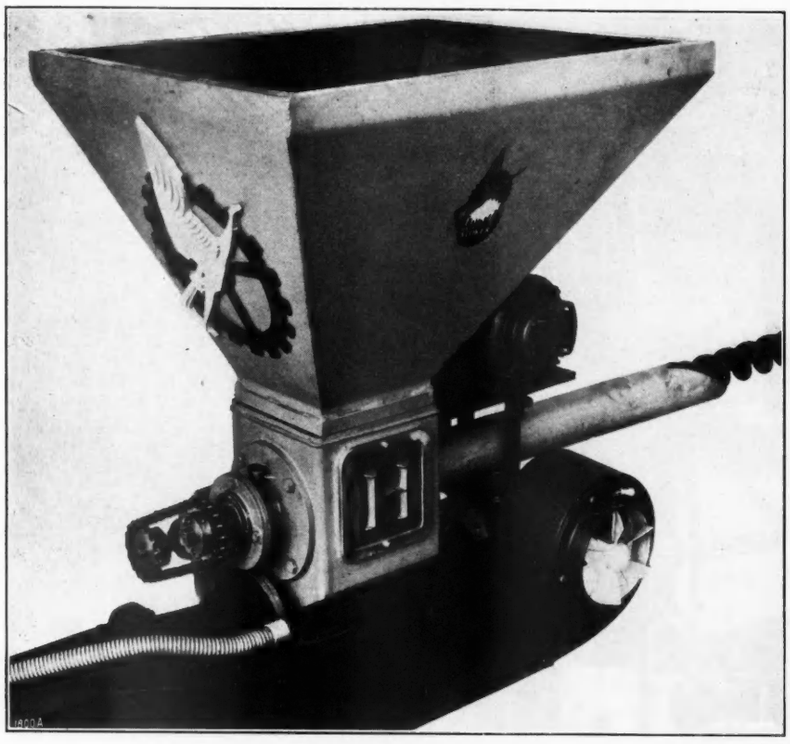


FIG. 1. STOKER WITH HOPPER FITTED.

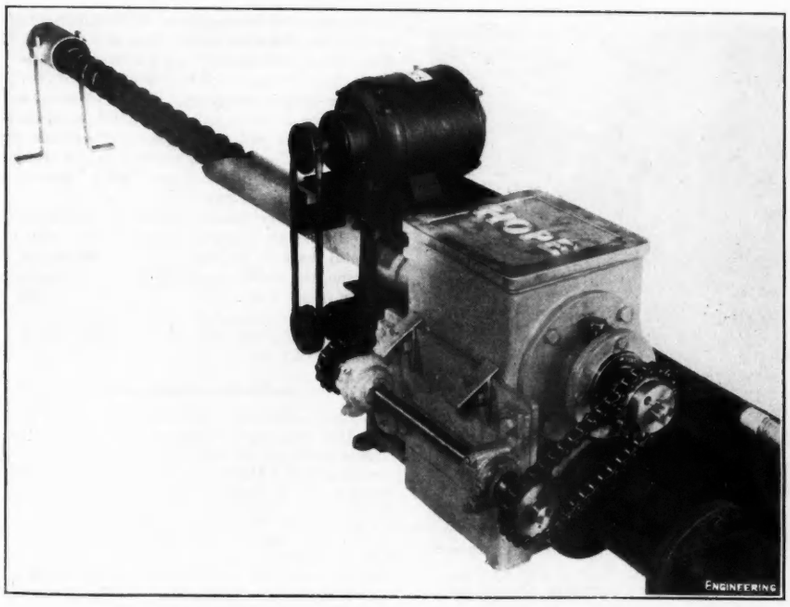
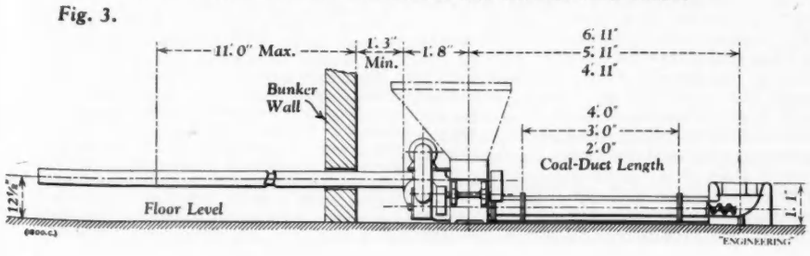


FIG. 2. STOKER WITHOUT HOPPER, SHOWING BUNKER FEED SCREW.

Fig. 3.



MECHANICAL STOKER WITH COMBINED BUNKER AND HOPPER FEEDS.

THE solid-fuel mechanical stoker illustrated herewith has been designed by the makers, Hope's Heating and Engineering, Limited, Smethwick, Birmingham, to combine in one machine automatic firing from both a bunker and a hopper. It is of the underfeed type, the feed to the retort (which is mounted in the boiler or furnace), being supplied by an Archimedean screw. In this respect it is similar to other stokers made by the company.

The main fuel supply is drawn from a bunker of any desired capacity, but a hopper can be mounted over the stoker-drive mechanism to provide a reserve which is always available, and comes into use automatically if there should be a stoppage, caused by foreign matter, in the main supply. The reserve hopper can be of any suitable capacity; it can, for example, be arranged to hold sufficient fuel to keep the stoker in operation during a period when it is left unattended, or when a stoppage in the main fuel supply would not be noticed.

To draw fuel from the bunker, an Archimedean screw of cast alloy steel is mounted at the back of the stoker-drive mechanism, and projects through the wall of the bunker, as shown in Fig. 3. The screw is guided at its two ends; at the front there is the feed tube to the stoker, and at the rear end there is a socket fixed inside the bunker. The remainder of the screw is open, and foreign matter in the fuel can fall past the screw to the bottom of the bunker, whence it can be cleared at intervals. Should a piece of foreign matter jam between the screw and the feed tube, a shear pin in the drive head is sheared off, and the screw stops. Meanwhile, the stoker draws its fuel from the reserve hopper.

The feed screw from the bunker delivers fuel to the bottom of the hopper, and immediately below this point is the second Archimedean screw, which feeds the fuel to the retort. In normal operation, therefore, the upper screw discharges to the lower, and the feed is continuous from the bunker to the retort. In the event of the bunker screw stopping, the fuel falls from the hopper past the idle screw to the one which is still running, and the feed continues without interruption.

The whole unit is driven by a single electric motor, which drives the two feed screws through a gearbox and roller chains, and the fan which provides air for combustion by means of a V-belt drive. The layout of motor, gearbox and chain drives can be seen in Fig. 2, which shows the stoker without the reserve hopper, and with the guards removed. The gearbox, which is of the worm type, is totally enclosed, and incorporates a ratchet drive to the feed screws, which is controlled by a manual selector giving four speeds of delivery and a neutral position. The rate of feed of the retort screw is slightly in excess of that extending into the bunker, so that under normal conditions of operation, when the feed is taken from the bunker, a small quantity of fuel is also drawn from the hopper. This ensures that the fuel in the hopper is kept moving slowly and obviates settlement, which, would prevent the hopper from delivering fuel when it was needed.

Air for combustion is provided by a low-speed multi-vane fan, the intake and air ducting for which are visible in Fig. 1. A radial-vane control on the fan intake provides infinitely-variable regulation of the air, from full flow to zero. A sheet-steel duct from the fan takes the air to a chamber surrounding the retort, from which it passes to the fire through tuyeres. A small quantity of air is bled from the main air duct and carried into the coal-feed screw tube, to provide a slight positive pressure where the screw enters the retort.

The stoker is produced in various sizes, the present smallest in the range having a capacity of 200,000 B.Th.U. per hour, which is equivalent to a feed of approximately 25 lb. of coal per hour. The largest stoker at present made has a capacity of 3,400,000 B.Th.U., or approximately 425 lb. of coal per hour. Typical details of a medium-sized stoker are: capacity in B.Th.U. per hour, 600,000; maximum rate of coal feed per hour, 75 lb.; minimum rate, 25 lb.; motor, 0·5 h.p.; maximum fan capacity, 400 cub. ft. per minute at 1-in. water gauge.

TURBINE-GEAR SHAVING MACHINE.

DAVID BROWN MACHINE TOOLS, LIMITED, MANCHESTER.

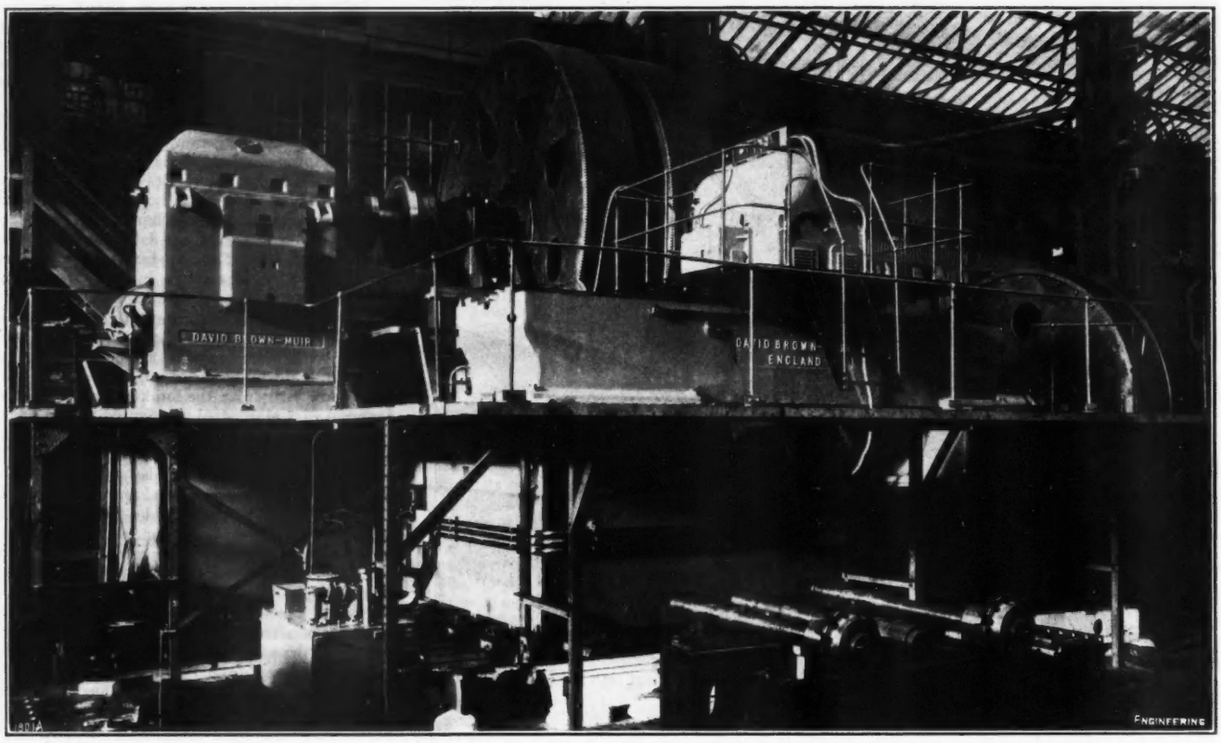


FIG. 1. VIEW SHOWING MAIN BED.

SHAVING MACHINE FOR 220-IN. GEARS.

A TURBINE-GEAR shaving machine, which is believed to be the largest in the world, is now in use at the Clydebank shipbuilding works of John Brown and Company, Limited. It has been designed and built by David Brown Machine Tools, Limited, Manchester, to accommodate turbine wheels of up to 220-in. diameter and weighing 100 tons. The machine itself weighs 130 tons. Fig. 1 shows it mounted on the shop floor as a temporary expedient so as not to delay an important shipbuilding contract, but it will ultimately be founded with the bottom of the bed 3 ft. below ground.

The machine is designed for "crowd" shaving of marine main propulsion wheels—a super-finishing process, shown in Fig. 2, for removing the minute undulations inherent in gears cut by the hobbing process. The main drive is from the headstock and through an Oldham coupling to the wheel which is being shaved. There is no rotational drive to the cutter, which is driven by contact with the main wheel. A power drive to the cutter head is solely for controlling the traverse of the saddle.

The machine is being used in conjunction with a David Brown 48-in. pinion-shaving machine which is employed for shaving high-pressure, intermediate-pressure and low-pressure pinions. The cutter head of the machine is equipped with an oil-cooled brake on each side of the cutter to permit selective shaving, which may be necessary to obtain something of the order of a 95 per cent. bearing across the face-width of the gear, allowing for slight relief at the ends. In cases where a precalculated amount has to be allowed for the torsional deflection of the pinion under full load, the necessary adjustment in the shaving process is carried out on the pinion machine. This usually applies to high-pressure pinions of comparatively small diameter. A feature of the machine is that it is fitted with a pinion-mounting bracket at the rear, allowing the machine to be used as a testing bed so that the tooth marking

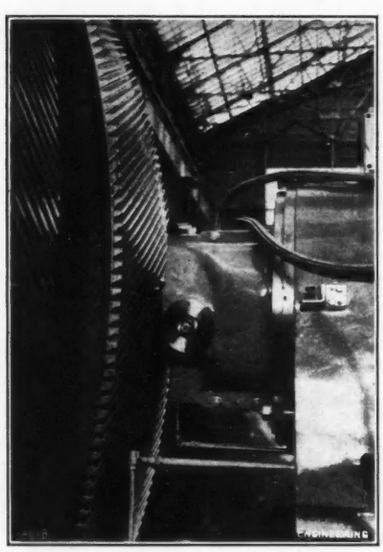


FIG. 2. SHAVING CUTTER IN OPERATION.

can be determined without removing the large wheel from the shaving machine.

The machine is 33 ft. long, with a fore-and-aft dimension of 35 ft. and a total height of 16 ft. The main bed comprises two heavily ribbed castings tenoned and bolted together, on which are mounted the shaving-head slide-bed, the wheel pedestals and the bracket for the pinion pedestals. By adjusting the shaving-head slide-bed on the main bed of the machine, gears of any centre distance from 48 in. up to the maximum diameter of 220 in. can be accommodated. The cutter has maximum traverse of 100 in., and a similar wheel-face width is within the capacity of the machine. With a bore of 2½ in. the cutter diameter ranges from 8 to 14 in. The main drive to the wheel is by a 30-h.p. motor, the work speed being variable between 7 and 30 r.p.m. by means of pick-off gears. The drive to the saddle feed motion is by an independent 6-h.p. motor and, by the use of pick-off change gears, saddle cross-feeds of between 0·03 in. and 0·7 in. are available. A self-contained motor-driven pump, strainer and oil reservoir unit is provided.

Small primary wheels can be accommodated by using pedestal supports mounted on the large pedestal bases. To facilitate the setting of the machine, the saddle is provided with a quick power motion of 36 in. a minute and the shaving head has a rapid traverse speed of 12½ in. a minute. Movement of the shaving head can be accomplished with a motion of 0·01 in. per revolution of the hand-wheel.

CONSTRUCTION OF TURBO-ALTERNATORS IN NORTHERN IRELAND.—New works, for the construction of large steam turbo-alternators suitable for use in power stations, are shortly to be erected at Larne, Northern Ireland, by the British Thomson-Houston Co., Ltd., Rugby. The company originally intended to build works capable of employing between 200 and 300 persons, but as the result of discussions with the Northern Ireland Ministry of Commerce it has been decided to proceed with the erection of a much larger establishment. The new works are expected ultimately to employ some 2,500 workpeople.

LETTERS TO SIR WILLIAM SIEMENS.—As recorded in our issue of May 22 last, on page 659, a collection of facsimile and printed copies of over 250 letters written to Sir William Siemens was presented to the Institution of Electrical Engineers by Sir George Nelson, chairman of the English Electric Company, Limited, on Thursday, May 14. We mentioned that a similar, but less elaborate, volume containing printed copies of the letters and a biography of Sir William had been prepared for presentation to universities, libraries and schools in the United Kingdom, the Dominions and the United States. Only a limited edition of this volume was printed, all copies of which have been earmarked and most of them have already been distributed.

COMBINED MAGNETISATION OF MAGNETIC MATERIALS.*

By J. E. PARTON, B.Sc., Ph.D., M.I.E.E., and W. D. SUTHERLAND, B.Sc., Ph.D., A.M.I.E.E.

(*Concluded from page* 700.)

BACK-TO-BACK METHOD OF CORE CONNECTION.

IT is felt that the technique of measurement of the core losses used throughout these tests is worthy of mention, since it is based on the back-to-back connection of two identical core units. This method of connection forms the basis of transductor and magnetic-amplifier circuits where one set of windings is energised from a direct-current or very low-frequency signal source and the other set carries the load current which is to be controlled. The application of this technique to facilitate iron-loss measurement under combined conditions is justified in a later sub-section.

Circuit Details.—Two exactly similar specimens of special Lohys were assembled from ring stampings. To ensure that each core had the same magnetic properties the ring stampings were subdivided and mixed until two cores of equal weight with 32 stampings each were obtained. Identical windings were put on each core and the cores were connected as shown in Fig. 16, page 700, *ante*. Each set of energising windings was connected in series and supplied from high-impedance sources with current waveforms

$$i_1 = \mathfrak{i}_1 \sin \omega t,$$
$$i_n = \mathfrak{i}_n \sin n\omega t.$$

By means of ammeter switches at points 1, 2 and 3 in Fig. 16, the components of the total-current wave can be obtained. For alternating-current potentiometer measurements a standard resistance was inserted at point 1 and the components of the magnetising force obtained. This necessitates special circuits for the potentiometer to enable it to read values first at one frequency and then, by suitable switching, to operate at a different frequency. The voltage components were measured from the voltage across the 400-turn search coils FB or GB (Fig. 16). This voltage is the total core voltage containing f_1, f_n and harmonics of both these components.

If the potentiometer gave the following results when operating at f_1, i.e.,

$$I_1 = a_1 + j\,b_1,$$
$$V_1 = c_1 + j\,d_1,$$

and when operating at f_2

$$I_2 = a_2 + j\,b_2,$$
$$V_2 = c_2 + j\,d_2,$$

the core-loss values are given by

$$W_1 = \frac{N_1}{N_2}(a_1 c_1 + b_1 d_1),$$

and

$$W_2 = \frac{N_n}{N_2}(a_2 c_2 + b_2 d_2).$$

In the test results $N_1 = N_n = 100$ and $N_2 = 400$, and the total core loss is given by $W_T = W_1 + W_2$.

Analytical Study of the Back-to-Back Connection.—The ideal mode of operation would give no voltage at the frequency of source 1 or harmonic components of it across source 2 terminals and, conversely, for source 1 terminals. Under these conditions, there can be no flow of harmonic power from source 1 to source 2, or vice versa. To obtain this condition with the given current waveforms the cores would require to present linear impedances, which is not the case, due to the effects of the core material. The voltage across each winding on the specimens will therefore contain harmonics. If these harmonic voltages cause currents to flow back through the sources then two effects occur. Firstly, due to the harmonic-current flow the core magnetisation is no longer

$$h = h_1 \sin \omega t + h_n \sin n\omega t$$

and, secondly, there will be a power loss in the supply resistances caused by the harmonic current. This harmonic power must be supplied from the fundamental power delivered to the cores, as a result of which any measurements to obtain the core loss will be greater than true loss since the

Fundamental-power input to specimen = total core loss + harmonic power.

The effect of harmonic-power flow will therefore be to increase the measured fundamental component of core loss.

To obtain analytically the voltage components across the source terminals under combined magnetisation conditions the core B-H relationship may be represented by the expression

$$B = a\,H + b\,H^3 + c\,H^5 \text{ (where } a, b \text{ and } c \text{ are constants).} \quad (5)$$

This expression neglects the effects of hysteresis and eddy currents but enables an estimation of the flux-density harmonic components to be readily obtained.

The magnetising force for core 1 is given by

$$h = h_1 \sin \omega t + h_n \sin n\omega t, \quad . \quad (6)$$

and the corresponding magnetising force for core 2 is

$$h = h_1 \sin \omega t - h_n \sin n\omega t, \quad . \quad (7)$$

(since the "$n\omega t$-winding" on core 2 is reversed).

Substituting equation (6) for H in equation (5), expanding and collecting terms the resulting flux density is

$$\begin{aligned} b_1 = {} & \text{A} \sin \omega t - \text{C} \sin 3\omega t + \text{D} \sin 5\omega t \\ & + \text{E} \sin (n-4)\omega t - \text{F} \sin (n-2)\omega t \\ & + \text{G} \sin n\omega t - \text{F} \sin (n+2)\omega t \\ & + \text{E} \sin (n+4)\omega t - \text{J} \sin (2n-3)\omega t \\ & + \text{K} \sin (2n-1)\omega t - \text{K} \sin (2n+1)\omega t \\ & + \text{J} \sin (2n+3)\omega t + \text{L} \sin (3n-2)\omega t \\ & - \text{M} \sin 3n\omega t + \text{L} \sin (3n+2)\omega t \\ & - \text{N} \sin (4n-1)\omega t + \text{N} \sin (4n+1)\omega t \\ & + \text{P} \sin 5n\omega t. \quad . \quad . \quad . \quad . \quad (8) \end{aligned}$$

Expressions for the quantities A to P in terms of the core constants a, b and c and the values of h_1 and h_n are given in a later sub-section.

From equation (8) which gives a general solution for the components of the core-flux density, it can be seen that, in addition to the harmonic components produced due to the magnetising force components ωt and $n\omega t$, intermodulation components are introduced, i.e., $(n-4)\omega t$, $(n+4)\omega t$; $(n-2)\omega t$, $(n+2)\omega t$; $(2n-3)\omega t$, $(2n+3)\omega t$; $(2n-1)\omega t$, $(2n+1)\omega t$; $(3n-2)\omega t$, $(3n+2)\omega t$; $(4n-1)\omega t$, $(4n+1)\omega t$ due to the combined magnetisation condition. When n is small, the above components give rise to a complete series of odd harmonic components. When n is large, the additional components occur at frequencies just above and just below the higher-frequency harmonic components.

The corresponding flux density components for core 2 are obtained by substituting equation (7) for H in equation (5). This gives

$$\begin{aligned} b_2 = {} & \text{A} \sin \omega t - \text{C} \sin \omega t + \text{D} \sin 5\omega t \\ & - \text{E} \sin (n-4)\omega t + \text{F} \sin (n-2)\omega t \\ & - \text{G} \sin n\omega t + \text{F} \sin (n+2)\omega t \\ & - \text{E} \sin (n+4)\omega t - \text{J} \sin (2n-3)\omega t \\ & + \text{K} \sin (2n-1)\omega t - \text{K} \sin (2n+1)\omega t \\ & + \text{J} \sin (2n+3)\omega t - \text{L} \sin (3n-2)\omega t \\ & - \text{M} \sin 3n\omega t - \text{L} \sin (3n+2)\omega t \\ & - \text{N} \sin (4n-1)\omega t + \text{N} \sin (4n+1)\omega t \\ & - \text{P} \sin 5n\omega t. \quad . \quad . \quad . \quad . \quad (9) \end{aligned}$$

The values of the components A to P in equation (9) are identical with those obtained previously in equation (8).

The voltage appearing across terminals A B, Fig. 16, under the assumed conditions of magnetisation may be readily obtained from the foregoing expressions for core-flux density: $v_{AB} = N_1 A_i \frac{d}{dt}(b_1 - b_2)$ where A_i = core cross-sectional area, m^2. The turns N_1 for core 1 are equal to N_2 for core 2.

By substitution from equations (8) and (9) for b_1 and b_2 the voltage across A B is obtained; this is

$$\begin{aligned} v_{AB} = {} & 2\omega N_1 A_i [n\text{G} \cos n\omega t - 3\,n\text{M} \cos 3n\omega t \\ & + 5n\text{P} \cos 5n\omega t \\ & + (n-4)\,\text{E} \cos (n-4)\omega t \\ & - (n-2)\,\text{F} \cos (n-2)\omega t \\ & - (n+2)\,\text{F} \cos (n+2)\omega t \\ & + (n+4)\,\text{E} \cos (n+4)\omega t \\ & + (3n-2)\,\text{L} \cos (3n-2)\omega t \\ & + (3n+2)\,\text{L} \cos (3n+2)\omega t]. \quad (10) \end{aligned}$$

Similarly the voltage across CB is

$$\begin{aligned} v_{CB} = {} & N_1 A_i \frac{d}{dt}(b_1 + b_2) \qquad (N_1 = N_2) \\ = {} & 2\omega N_1 A_i [\text{A} \cos \omega t - 3\,\text{C} \cos 3\omega t \\ & + 5\,\text{D} \cos 5\omega t - (2n-3)\,\text{J} \cos (2n-3)\omega t \\ & + (2n-1)\,\text{K} \cos (2n-1)\omega t \\ & - (2n+1)\,\text{K} \cos (2n+1)\omega t \\ & + (2n+3)\,\text{J} \cos (2n+3)\omega t \\ & - (4n-1)\,\text{N} \cos (4n-1)\omega t \\ & + (4n+1)\,\text{N} \cos (4n+1)\omega t.] \quad (11) \end{aligned}$$

From equations (10) and (11) it is seen that the voltages appearing across each set of energising windings E B and D B, on the cores in Fig. 16 contain fundamental + harmonic components of one supply and additionally certain "intermodulation products" as given above. (The winding resistances are assumed to be negligible.)

The voltage across the winding on one core only, i.e., F B, is

$$\begin{aligned} v_{FB} = {} & N_1 A_i \frac{db_1}{dt} \\ = {} & \omega N_1 A_i [\text{A} \cos \omega t - 3\,\text{C} \cos 3\omega t \\ & + 5\,\text{D} \cos 5\omega t + (n-4)\,\text{E} \cos (n-4)\omega t \\ & - (n-2)\,\text{F} \cos (n-2)\omega t \\ & + n\,\text{G} \cos n\omega t - (n+2)\,\text{F} \cos (n+2)\omega t \\ & + (n+4)\,\text{E} \cos (n+4)\omega t \\ & - (2n-3)\,\text{J} \cos (2n-3)\omega t \\ & + (2n-1)\,\text{K} \cos (2n-1)\omega t \\ & - (2n+1)\,\text{K} \cos (2n+1)\omega t \\ & + (2n+3)\,\text{J} \cos (2n+3)\omega t \\ & + (3n-2)\,\text{L} \cos (3n-2)\omega t \\ & - 3n\,\text{M} \cos 3n\omega t \\ & + (3n+2)\,\text{L} \cos (3n+2)\omega t \\ & - (4n-1)\,\text{N} \cos (4n-1)\omega t \\ & + (4n+1)\,\text{N} \cos (4n+1)\omega t \\ & + 5n\,\text{P} \cos 5n\omega t]. \quad . \quad . \quad (12) \end{aligned}$$

From equations (10) and (11) it is seen that the effect of the back-to-back connection when compared with single-core excitation (equation 12) prevents a large percentage of the harmonic-voltage terms generated in each core from appearing across the source terminals.

For the case when n is large the voltage appearing across the "ωt" source consists of harmonics of ωt + higher order terms in n. Similarly, the voltage across the "$n\omega t$"-source consists of harmonics of $n\omega t$ + higher order terms in n. If large air-cored inductances are inserted in the supply circuits, the impedance presented to the harmonic voltages will restrict the flow of harmonic current to negligible proportions.

When n is small the intermodulation products give rise to voltage components at the harmonic frequencies of each source. This case is illustrated for $n = 3$. The voltages appearing across the exciting windings of the cores when subjected to sine-current excitation are then given by

$$\begin{aligned} v_1 = {} & 2\omega N_1 A_i [\text{A} \cos \omega t - 3\,(\text{C} + \text{J}) \cos 3\omega t \\ & + 5\,(\text{D} + \text{K}) \cos 5\omega t - 7\,\text{K} \cos 7\omega t \\ & + 9\,\text{J} \cos 9\omega t - 11\,\text{N} \cos 11\omega t \\ & + 13\,\text{N} \cos 13\omega t]. \quad . \quad . \quad . \quad (13) \end{aligned}$$

and

$$\begin{aligned} v_2 = {} & 2\omega N_1 A_i [(-\text{E} + \text{F}) \cos \omega t + 3\,\text{G} \cos 3\omega t \\ & - 5\,\text{F} \cos 5\omega t + 9\,(\text{E} + \text{L}) \cos 7\omega t \\ & - 9\text{M} \cos 9\,\omega t + 11\text{L} \cos 11\,\omega t \\ & + 15\,\text{P} \cos 15\,\omega t]. \quad . \quad . \quad . \quad (14) \end{aligned}$$

From these equations it would at first sight appear that the use of the back-to-back connection was of little advantage due to the presence of $3\,\omega t$

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and ωt terms across the "ωt" and "$3\omega t$" sources, respectively. The magnitude of the coefficients of these terms is small and it is found that they do not in any way detract from the method, provided the source impedances are relatively large in comparison with the core-winding impedance.

The corresponding voltage across one core winding, i.e. F B, Fig. 16, when $n = 3$ is obtained from equation (12).

$$= \omega N_1 A_i [(A - E - F)\cos\omega t - 3(C + J - G)\cos 3\omega t + 5(D + K - F)\cos 5\omega t - 7(K - E - L)\cos 7\omega t + 9(J - M)\cos 9\omega t + 11(L - N)\cos 11\omega t + 13 N \cos 13\omega t + 15 P \cos 15\omega t]. \quad (15)$$

It is seen from equation (15) that the effect of the intermodulation when $n = 3$ is to alter the magnitude of the true harmonic terms (ωt, $3\omega t$, $5\omega t$, $9\omega t$ and $15\omega t$) by amounts depending on the magnitudes of h_1, h_3 and the core constants b and c. The remaining terms $7\omega t$, $11\omega t$ and $13\omega t$ are set up solely by intermodulation, since the normal core harmonic components are only considered up to and including the 5th in this analysis (see equation (5)). To illustrate the actual magnitudes of the induced voltage wave components the circuit of Fig. 16 was energised from 50-cycle and 150-cycle supply units. A dynamometer wattmeter was used with its current coil energised from a variable-frequency oscillator and its voltage coil connected across a search winding on the specimen. When the oscillator frequency is just below or just above a harmonic component in the voltage wave, the wattmeter pointer will oscillate. By adjustment of the oscillator frequency the maximum pointer deflection can be easily read; this value is proportional to the harmonic component provided the current-coil excitation is constant.

The following voltage components were obtained under typical core excitation conditions (Table III).

(1) Across one core, i.e. wattmeter voltage coil across 400-turn winding.
(2) Across the 50-cycle energising terminals (voltage coil across 800 turns, C B).
(3) Across the 150-cycle energising terminals (voltage coil across 800 turns, A B).

Since the two cores were not subjected to the same conditions of magnetisation,

$$\text{(Core 1 : } h = h_1 \sin\left(\omega t + \frac{\pi}{3}\right) + h_3 \sin 3\omega t,$$

$$\text{Core 2 : } h = h_1 \sin\left(\omega t + \frac{\pi}{3}\right) - h_3 \sin 3\omega t),$$

the results for Core 1 cannot be directly compared with v_{CB} and v_{AB}. It must also be noted that there is a factor of 2 in these latter cases due to the wattmeter voltage coil being connected across two 400-turn windings in series.

These numerical values may be identified proportionally with the coefficient values obtained under the assumption of a single-line magnetisation characteristic. The numerical values of the coefficients for Core 1 are given in column A of Table IV. The corresponding values obtained from the summation of coefficient values for V_{50} and V_{150} are given in column B.

It is seen that due to the effects of hysteresis and eddy currents, the 50-cycle coefficients differ by 22 per cent., the 150-cycle by 7 per cent., and the higher orders by less than this figure. This would be expected since the B-H relationship is now a double-valued function of H, and consequently the operating points for given magnetising force values in each core will give in one case a larger and in the other case a smaller flux-density value than obtained from a single-line characteristic. Due to the non-linearity of the B-H relationship, the flux changes in the two cases for the same magnetising force are not equal.

It should also be noted that under combined conditions, the magnitude of the 150-cycle voltage component appearing across the 50-cycle supply (3C + 3J) is 16 per cent. of the 50-cycle value (A) in this test. Similarly, the 50-cycle voltage (E + F) across the 150-cycle supply is 26 per cent. of the 150-cycle value (3G). Without the back-to-back connection of cores the corresponding values are 110 per cent. and 85 per cent., respectively. Due to the relatively large percentage of 50-cycle and 150-cycle voltage components still appearing across the 150-cycle and 50-cycle supply units with the back-to-back connection, it was necessary to ensure that the supply current waveforms were sinusoidal. By a similar method to that used to obtain the voltage components it was found that with the standard test circuit and supply units the cores were subjected to practically perfect conditions of sine-current excitation since the individual harmonic components in the 50-cycle and 150-cycle current waves were less than 0·2 per cent. for all values of the relative phase angle ϕ. These test results were obtained for the maximum value of core magnetising force components used in the tests. The exciting-current values were reduced by the increase of circuit resistance to obtain other test conditions. This resistance would tend to suppress the harmonic components in the current wave even further. Hence it can be stated that under all test conditions and relative phase angles, the cores were subjected to sine-current magnetisation.

TABLE III.

f	50	150	250	350	450	550	650 cycles per sec.
V_T (Core 1)	0·23	0·27	0·16	0·15	0·11	0·07	0·01
V_{CB}	0·49	0·08	0·11	0·25	0·15	0·05	0·06
V_{AB}	0·13	0·5	0·24	0·08	0·07	0·08	—

TABLE IV.

f cycles per sec.	Core 1	(A)	V_{50}		V_{150}		$V_{50} + V_{150}$	2 (B)	B
50	A — E — F	0·23	2A	0·49	— 2(E + F)	0·13	2A — 2(E + F)	0·62	0·31
150	— 3(C + J — G)	0·27	— 6(C + J)	0·08	6G	0·5	— 6(C + J — G)	0·58	0·29
250	5(D + K — F)	0·16	10(D + K)	0·11	— 10F	0·24	10(D + K — F)	0·35	0·175
350	— 7(K — E — L)	0·15	— 14K	0·25	14(E + L)	0·08	— 14(K — E — L)	0·33	0·165
450	9(J — M)	0·11	18J	0·15	— 18M	0·07	18(J — M)	0·22	0·11
550	11(L — N)	0·07	— 22N	0·05	22L	0·08	22(L — N)	0·13	0·065
650	13N	0·01	26N	0·06	26N	—	52N	0·06	0·015
750	15P	—	—	—	30P	—	—	—	—

Coefficient Values.—Values of A to P used in equation (8) *et seq.* in terms of the constants from the basic core magnetisation characteristic, equation (5), and the magnetising force values h_1 and h_n, are

$$A = a h_1 + \tfrac{3}{4} b h_1^3 + \tfrac{3}{8} b h_1 h_n^2 + \tfrac{5}{8} c h_1^5 + \tfrac{15}{4} c h_1^3 h_n^2 + \tfrac{15}{8} c h_1 h_n^4$$
$$C = \tfrac{1}{4} b h_1^3 + \tfrac{1}{16} c h_1^5 + \tfrac{5}{4} c h_1^3 h_n^2$$
$$D = \tfrac{1}{16} c h_1^5$$
$$E = \tfrac{5}{16} c h_1^4 h_n$$
$$F = \tfrac{3}{4} b h_1^2 h_n + \tfrac{5}{4} c h_1^4 h_n + \tfrac{15}{8} c h_1^2 h_n^3$$
$$G = a h_n + \tfrac{3}{4} b h_n^3 + \tfrac{3}{8} b h_1^2 h_n + \tfrac{5}{8} c h_n^5 + \tfrac{15}{4} c h_1^2 h_n^3 + \tfrac{15}{8} c h_1^4 h_n$$
$$J = \tfrac{5}{8} c h_1^3 h_n^2$$
$$K = \tfrac{3}{4} b h_1 h_n^2 + \tfrac{15}{8} c h_1^2 h_n^2 + \tfrac{5}{4} c h_1 h_n^4$$
$$L = \tfrac{5}{8} c h_1^3 h_n^2$$
$$M = \tfrac{1}{4} b h_n^3 + \tfrac{1}{16} c h_n^5 + \tfrac{5}{4} c h_1 h_n^3$$
$$N = \tfrac{5}{16} c h_1 h_n^4$$
$$P = \tfrac{1}{16} c h_n^5$$

In conclusion, the authors wish to thank Professor B. Hague, of the Electrical Engineering Department, University of Glasgow, for providing facilities and for much helpful advice and encouragement.

LAUNCHES AND TRIAL TRIPS.

M.S. "THEBEN."—Single-screw cargo vessel, with accommodation for twelve passengers, built and engined by Eriksbergs Mekaniska Verkstads A/B, Gothenburg, Sweden, for Wilh. Wilhelmsen, Tönsberg, Norway. Main dimensions: 470 ft. by 65 ft. by 43 ft. to shelter deck; deadweight capacity, 10,575 tons on a draught of 27 ft. 7½ in. Eriksbergs-Burmeister and Wain ten-cylinder two-stroke single-acting Diesel engine, developing 11,500 i.h.p. Speed, 18 knots fully loaded. Trial trip, September 24.

M.S. "SARSIA."—Single-screw trawler for marine biological and oceanographical research, built by Philip and Son, Ltd., Dartmouth, for the Marine Biological Association of the United Kingdom, Plymouth. Main dimensions: 128 ft. overall by 28 ft. by 13 ft.; mean draught, 9 ft. 6 in. Six-cylinder four-stroke Diesel engine coupled to the propeller shaft through oil-operated reverse reduction gears with 3:1 ratio, developing 270 s.h.p. at 450 r.p.m. in service, constructed by the National Gas and Oil Engine Co., Ltd., Ashton-under-Lyne. Speed, 10 knots. Trial trips, October 15 and 21.

M.S. "ØSTERSØEN."—Single-screw vessel with accommodation for 500 passengers, built and engined by Burmeister and Wain Ltd., Copenhagen, for A/S Dampskibsselskabet paa Bornholm af 1866, Bornholm, Denmark. Hull constructed by A/S Svendborg Skibsværft, Svendborg, Denmark. Main dimensions: 174 ft. 4 in. overall by 34 ft. 5 in. by 22 ft. to upper deck; gross tonnage, about 1,100; mean draught, 11 ft. 3 in. Eight-cylinder two-stroke single-acting Diesel engine, developing 2,000 i.h.p. at 290 r.p.m. Speed, about 13 knots. Launch, October 16.

M.S. "BRITISH OAK."—Single-screw oil tanker, built by Smith's Dock Co., Ltd., South Bank-on-Tees, for the British Tanker Co., Ltd., London, E.C.2. Main dimensions: 515 ft. between perpendiculars by 69 ft. 6 in. by 37 ft. 6 in.; deadweight capacity, 15,882 tons on a draught of about 30 ft. Six-cylinder two-stroke single-acting opposed-piston Diesel engine, developing 6,400 b.h.p. at 114 r.p.m., constructed by Harland and Wolff, Ltd., Belfast, and installed by the shipbuilders. Service speed, 13¼ knots. Trial trip, October 17.

M.S. "MARGIT."—Single-screw cargo vessel, built by the Nakskov Shipyard, Ltd., Nakskov, Denmark, for the Myren Steamship Co., Ltd., Copenhagen. Main dimensions: 405 ft. between perpendiculars by 57 ft. 6 in. by 36 ft. 9 in. to shelter deck; cargo capacity, about 535,000 cub. ft. Six-cylinder single-acting two-stroke Diesel engine, developing 4,100 b.h.p. at 100 r.p.m., constructed by Burmeister and Wain, Ltd., Copenhagen, Denmark. Speed, 14 knots, fully loaded. Trial trip, October 23.

S.S. "DEVONBROOK."—Single-screw cargo vessel, built and engined by John Lewis and Sons, Ltd., Aberdeen, for the Williamstown Shipping Co., Ltd. (Managers: Comben Longstaff & Co., Ltd.), London, E.C.3. Main dimensions: 225 ft. between perpendiculars by 35 ft. 6 in. by 15 ft. 9 in. to upper deck; deadweight capacity, about 1,600 tons. Triple-expansion steam engine and two oil-burning Scotch boilers. Launch, October 24.

S.S. "WATERLOO."—Single-screw tug, built by Cochrane and Sons, Ltd., Selby, Yorkshire, for the Alexandra Towing Co., Ltd., Liverpool. Main dimensions: 92 ft. 6 in. between perpendiculars by 25 ft. 6 in. by 12 ft. 6 in.; gross tonnage, 200. Triple-expansion steam engine developing 800 i.h.p., constructed by Charles D. Holmes & Co., Ltd., Hull. Launch, October 24.

M.S. "THOMAS LIVESEY."—Single-screw collier, built by S. P. Austin and Son, Ltd., Sunderland, for the North Thames Gas Board, London, W. 8. (Managers: Stephenson Clarke, Ltd., London, E.C.3). Main dimensions: 257 ft. by 39 ft. 6 in. by 18 ft. 6 in.; deadweight capacity, about 2,700 tons on a mean summer draught of 17 ft. 1 in. Clark-Sulzer eight-cylinder single-acting two-stroke oil engine, developing about 1,280 b.h.p. at 225 r.p.m., constructed by George Clark (1938), Ltd., Sunderland. Trial speed exceeded 11 knots. Trial trip, October 28.

S.S. "CALTEX MANCHESTER."—Single-screw oil tanker, built and engined by R. and W. Hawthorn, Leslie & Co., Ltd., Hebburn-on-Tyne, County Durham, for the Overseas Tankship (U.K.), Ltd., London, W.1. Main dimensions: 544 ft. 4 in. overall by 70 ft. by 39 ft. 9 in. to upper deck; deadweight capacity, about 17,450 tons. Double-reduction geared steam turbines, developing a maximum of 8,200 s.h.p., and two Yarrow water-tube marine boilers. Speed, 15 knots. Trial trip, October 30.

S.S. "RATHLIN HEAD."—Single-screw cargo vessel, with accommodation for twelve passengers, built and engined by Harland and Wolff, Ltd., Belfast, for the Ulster Steamship Co., Ltd. (Managers: G. Heyn and Sons, Ltd.), Belfast. Main dimensions: 405 ft. between perpendiculars by 58 ft. 9 in. by 39 ft. to shelter deck; gross tonage, about 7,350. Double-reduction geared steam turbines, developing 5,000 s.h.p. in service and two Babcock and Wilcox oil-burning boilers. Trial trip, November 3.

LIQUID-FUEL TURBO-STARTER FOR GAS TURBINES.

PLESSEY CO., LTD., ILFORD.

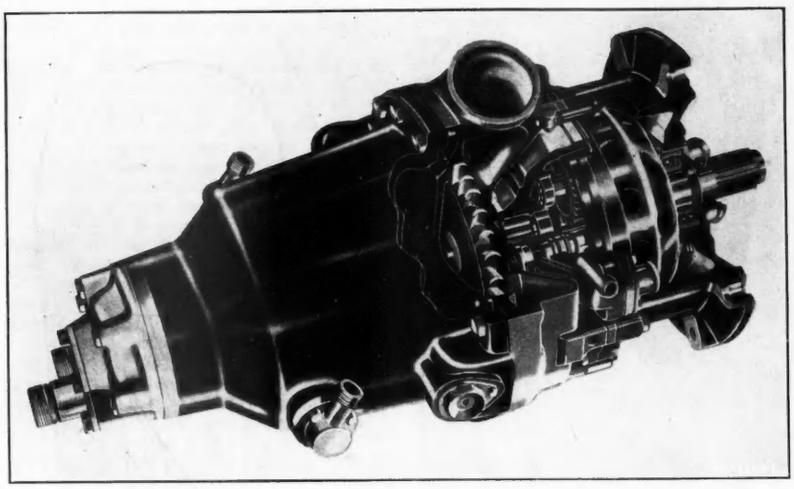
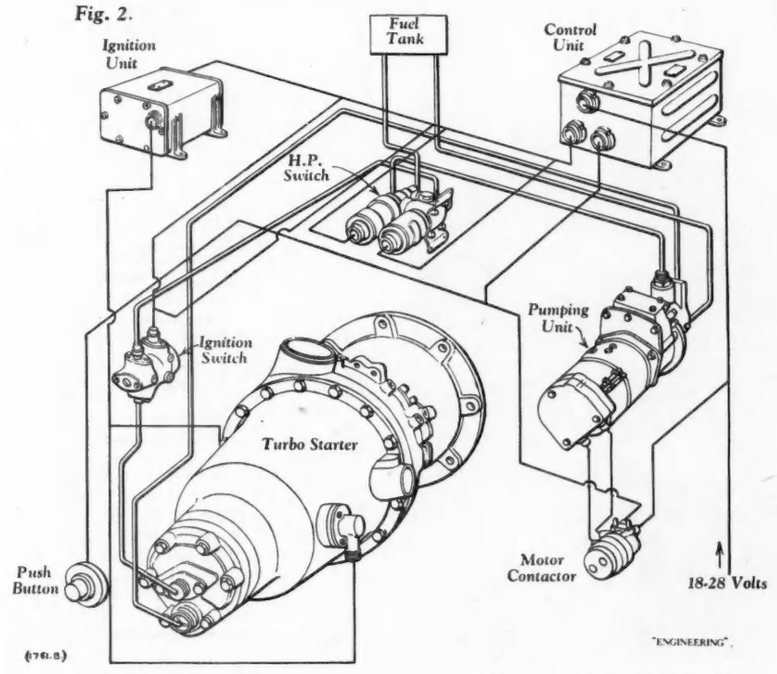


FIG. 1.

Fig. 2.



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LIQUID-FUEL TURBO-STARTER FOR GAS TURBINES.

ALL fighter aircraft of the Royal Air Force are required to be fitted with self-contained starters capable of running up their engines to idling speed within 10 seconds. With the powerful jet engines of high rotational inertia that are fitted to modern fighter aircraft about to come into service, the cartridge-type turbo-starter currently used, requiring large cordite cartridges, presents considerable difficulties in installation. During the past three years, therefore, the Plessey Company, Limited, Ilford, Essex, have been carrying out experimental work on a liquid monofuel turbo-starter system, which can be made much lighter and more compact than the cartridge design and has the advantage that the fuel can be stowed in a tank remote from the turbine unit itself. The firm have developed successfully two monofuel turbo-starters, giving average powers of 70 h.p. and 150 h.p., with peak powers of 140 h.p. and 300 h.p., respectively. The smaller unit, illustrated in Fig. 1, with part of the casing cut away to show the turbine and reduction gearing, has completed its type approval tests. Apart from a larger combustion chamber and pumping unit, the components of the 150-h.p. starter-system are identical with those of the smaller unit.

The fuel chosen for the Plessey turbo-starter, iso-propyl nitrate, behaves as a monofuel (i.e., it combusts spontaneously without an oxidant), at a pressure of about 100 lb. per square inch and a temperature of 200 deg. C. At atmospheric pressure and temperature, however, it does not ignite spontaneously but burns slowly in a manner similar to methylated spirit, and can readily be extinguished by water or carbon dioxide. It is non-toxic and is not shock-sensitive. In operation, therefore, it is necessary to supply the turbo-starter initially with a mixture of air and fuel and to fire it by a spark, until combustion is established and the temperature and pressure in the combustion chamber are sufficient to enable the fuel to decompose.

The arrangement of the starting system is shown in the diagram reproduced in Fig. 2. The turbo-starter unit itself comprises a combustion chamber fitted with a spray head and two igniter plugs, and an impulse turbine driving an output shaft through reduction gearing. The starting sequence is controlled by a time switch in the control unit, brought into operation by a single push-button switch in the cockpit. As soon as the pilot operates this push-button, the time switch closes the contactor of the pumping unit motor, which drives a Roots blower and a gear-type fuel pump operating at 7,000 r.p.m. Air is then pumped by the blower to scavenge the combustion chamber, and to provide the air supply required to initiate combustion; meanwhile the fuel pump circulates fuel through a by-pass valve, controlled by a solenoid, back to the fuel tank.

The scavenge period lasts for two to three seconds; at the end of this period the time switch opens the solenoid valve and fuel is pumped to the spray head in the combustion chamber. The rise in pressure in the fuel pipeline causes a pressure switch to close and bring into action a high-frequency ignition unit which energises the two sparking plugs and fires the mixture. When the pressure and temperature in the combustion chamber have risen sufficiently for the monofuel to decompose and burn spontaneously, the air supply to the combustion chamber is shut off by a valve and the ignition unit is switched off. When the turbine has attained its maximum speed—12,000 r.p.m. on the output shaft—a speed-sensitive switch shuts off the electrical supply to the starting system and the pumping unit closes down. This normally takes place some four or five seconds after ignition. To avoid the accumulation of unburnt fuel in the chamber in the event of failure to ignite, or the flame becoming extinguished, a high-pressure switch in the fuel line operates a relay in the control unit which shuts down the complete system.

The turbine blades, which are exposed to a temperature of about 450 deg. C., are made by the investment casting process in a specially developed material of the Stellite type. The turbine rotor, which is carried in a splash-lubricated ball and roller bearing, extends through a labyrinth seal into the reduction gearbox housing. A gear mounted on the end of the rotor shaft engages with three planetary pinions, the shafts of which are mounted on roller bearings in the housing. The planet gears drive a floating ring gear which is coupled directly to the output shaft, the end of which is splined to take the engine reduction gear. Experimental work on materials for the combustion chamber, which has to withstand a temperature of 1,000 deg. C., is still in hand, but ordinary mild steel has been used successfully in the unit which has recently completed its type tests and has now run some 1,100 hours with no replacements other than gaskets and seals. The spray head, which provides the fuel and air inlet to the combustion chamber, has swirl-type atomisers. To protect the combustion chamber against excessive pressures, should they arise in emergency, it is provided with safety discs which fracture when the pressure within the chamber reaches a critical value, allowing the gases to escape into the exhaust duct.

The ignition unit is of the Napier-Plessey high-frequency type, which is capable of producing powerful sparks at the rate of 50 per second, even when the plugs are caked or flooded with oil. It operates within the voltage range 18 to 29 volts. The unit comprises a vibrator transformer that produces an oscillatory high voltage which is applied to the primary of a high-frequency transformer. The resulting high-frequency oscillations from the transformer secondary are used to ionise the sparking plug gap, across which is discharged the energy stored by a capacitor in the vibrator-transformer primary circuit. The sequence, which is repetitive, is controlled by the vibrator-transformer interruptor.

PARSONS MEMORIAL LECTURE.—"Continuity of Electricity Supply" has been chosen as the subject for the 1953 Parsons Memorial Lecture, which will be delivered at the Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2, on Thursday, January 7, 1954, at 5.30 p.m. The lecturer will be Mr. H. Leyburn, B.Sc., M.I.E.E.

DYNAMIC TESTING OF WIRE ROPES AND THEIR FASTENERS.

ONE of the chief causes of failure in wire ropes arises from the means available for anchoring or joining the ropes or for attaching loads either at the ends or at points in the rope length. Various methods are used for these purposes; some cause obvious damage to the ropes, but it is considered that the defects of the better methods are not brought to light by static tensile tests, which produce failure of the ropes in their free lengths.

To devise more efficient methods, development work was begun over ten years ago and as a result the wire-rope fastenings shown in Figs. 1 to 3 have been developed, together with the test equipment shown in Fig. 4. The makers of these fasteners are E. H. Bentall and Company, Limited, Heybridge Works, Maldon, Essex. During the period of development the fastener was subjected to a series of static tensile tests at the Industrial Research Laboratories, Birmingham, and they also observed dynamic tests made by this company. Reports that have been published* state that the fastener exerts a secure hold, without slip, even when the applied load causes the destruction of the rope. Tests also made on conventional spliced ropes and fastenings in accordance with British Standard 463-1943 indicated that failure occurred earlier in the life of the rope so fitted and sometimes within the recommended fastenings.

The construction of the wire-rope fastenings illustrated ensures that each strand of the rope is held separately, evenly, and securely, between helically-formed gripping surfaces, which almost enclose the strand. The arrangement is such that the initial differences of strand lay are rectified when the rope comes under load, without detriment to the security of the attachment, so that each strand takes its full share of the load, and it is believed that the rope life is increased for this reason, up to as much as double, under the most arduous conditions of loading. The fasteners are designed so that the gripping pressure at all points is radial to the axis of the rope to give a compact assembly. In the case of the type-B fastening, Figs. 1 and 2, the axial length of the gripping surface is $2\frac{3}{8}$ times the rope diameter. The fasteners are made in two types: type A for mid-cable connections and type B for end connections.

In the type-A fastener, Fig. 3, the core of the rope is fortified by a metal bead, formed with helical grooves in which the strands of the rope lie. This bead may be solid, or hollow and split, depending upon whether the hemp core of the rope is to be partially removed or retained. In the case of a steel rope, such as a seven-strand rope, the centre core or strand may be gripped in the same way as the overlaid strands. As can be seen in Fig. 3, the outer members are also grooved helically to fit over the strands. When the parts have been assembled at the required point on the rope, axial pressure is applied, and each strand is gripped between the appropriate outer and inner members. The outer members may be made to any form to meet the needs of individual applications, or they may form on the rope a double cone which is suitable for the attachment of a variety of fittings. In one static test that was made on this type of fastening, a rope $\frac{11}{16}$ in. in diameter was used. It had six strands each of 12 wires and seven hemp cores, the wires being galvanised. The breaking load of the rope was given as 12·30 tons; the specimen used broke at 12·81 tons and no damage occurred to the fastener although complete failure of the rope took place at a point beyond the fastening. Fig. 3 is an illustration of the fastening used (a design which has since been modified); it was cut open after the test for inspection, as shown.

* "Some Live Load Tests on Wire Ropes and Fittings" by T. E. Dimbleby, A.M.I.Mech.E. Paper read before the Midland Branch of the Institution of Mechanical Engineers, on November 15, 1951; and Report of Dynamic Test of Type B Rope Grips, conducted by the Industrial Research Laboratories, Birmingham.

DYNAMIC TESTING OF WIRE-ROPE FASTENERS.

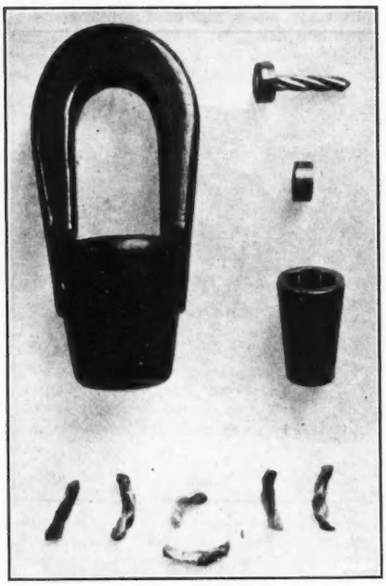


FIG. 1. COMPONENTS OF FASTENER FOR SOCKET.

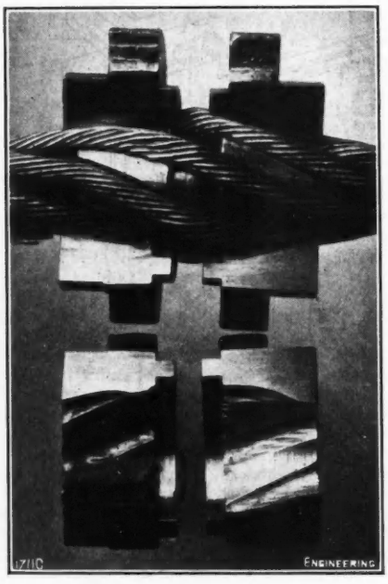


FIG. 3. MID-ROPE FASTENER AFTER TEST.

Fig. 2.

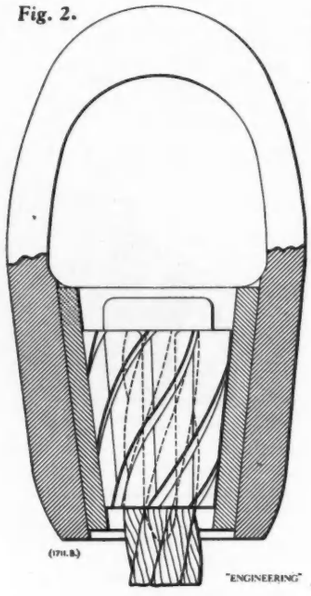
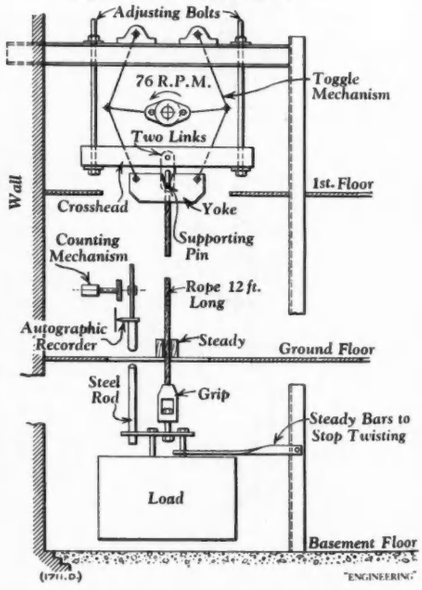


Fig. 4. TESTING MACHINE.



The type-B end fastening shown in Figs. 1 and 2 has more elements than the type A. In its simplest form, this fastening consists of a core-pin, one helical segment to each strand of the rope, and usually a sleeve. The core-pin, which fits into the end of the rope, is grooved helically to suit the lay of the strands and has a head which is made to abut on the end of the strands. The segments are grooved to fit the strands and when they are assembled on the rope they form a fluted cone. This cone fits into the sleeve shown, which has a taper bore and is fluted to receive it. Axial pressure exerted on the head of the core-pin securely fixes the various parts to the rope. If the fitting to which the rope has to be attached can be bored and fluted to receive the fastening assembly, the sleeve may be omitted, otherwise the fitting is bored to receive the sleeve with the rope end and the assembled parts inside it.

The extent of tests carried out on this fastening was considerable, and because the company wished to make tests more nearly representative of conditions experienced in actual service the dynamic testing machine previously mentioned was built. A series of static tests was also applied to this fastening.

The general arrangement of the dynamic testing machine is shown in Fig. 4. In view of the height required to obtain satisfactory conditions for the test, the machine was built between three floors of a building. The main members are constructed from steel channel and the end of the top beam is cemented into the adjacent wall. A crosshead is suspended from the beam, with two long bolts to facilitate raising and lowering the crosshead when setting up for a test. Two links hang from the centre of the crosshead, with elongated holes cut in them. The pin which is used to support the specimen to be tested fits in these holes and it is sufficiently long to extend either side of the links to a yoke. The yoke, also, is suspended from the main beam by links, which form a toggle mechanism, and the centres of the links are coupled to a crankshaft driven at 76 r.p.m.; this mechanism can

raise and lower the pin carrying the specimen a maximum distance of 2½ in. A heavy flywheel is mounted on the drive shaft. At the lower part of the test equipment there is a counting and autographic recorder which is connected to the suspended load by a rigidly mounted steel rod. To set the machine for a test, the drive shaft is put in motion, operating the toggle mechanism; the crosshead is lowered by its supporting screws until the yoke, at the top of its stroke, just touches the pin supporting the specimen. To make the test, the crosshead is lowered further to give the working stroke decided upon for the test, so that each time the yoke rises the supporting pin is raised suddenly by this amount and dropped back again, its fall being arrested by the slots of the two links in which it is carried. Thus, two sudden applications of the load are imposed on the specimen for each revolution of the drive shaft, or 152 blows per minute.

In one of the tests made on this machine a ½-in. diameter cable of 6/19 construction (six strands, each of 19 wires) and a listed breaking load of 8·1 tons was used. It had a thimble spliced at the upper end and at the lower end a fitting was attached by the B type of fastener. From this a dead load of 15 cwt. was suspended. The length of the fastener was 1⅛ in. The fall of the pin was set for ⅝ in. After five minutes of running, the splice became too warm to touch and grease oozed out from behind the strands. After 35,718 blows the splice pulled out, but the fastener showed no sign of slip. The damaged splice was cut off and a socket was attached to the rope by metalling in accordance with B.S.S. 463. The test was then continued up to 2,100,000 blows without fracture.

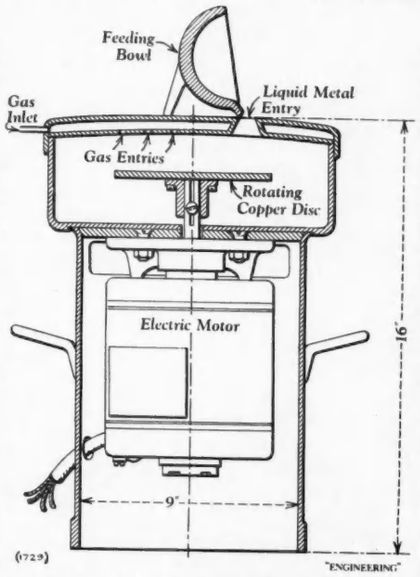
As the load could not be increased due to slip occurring on the driving belt, further tests were planned with a ⅜-in. diameter cable. In the test that followed, the cable was 12 ft. long with six strands each having 19 wires; its listed breaking load was 4·1 tons. The length of the contact between the cable and the segments was ⅞ in. and the nominal load was 15 cwt., as before. The first period of the test lasted six hours and 59,400 blows were recorded; at this stage the rope appeared to have stretched and a few wires were broken near the middle of the rope. It failed during the next period of test after 71,700 blows had been recorded. Two strands had broken near the fastener, three had broken from ¼ in. to ⅜ in. above it and the sixth had broken about 1½ in. above. The rope was also splintered at 46 places along its length. None of the wires had pulled out of the fastener, the segments were uniformly indented by the rope and the wires themselves were undamaged. During the tests no spreading, bending or displacement of the wires or of the strands occurred.

The fastener can be applied to ropes of any size. Various modifications to the fastener can be made to suit individual requirements, and by a combination of the two types of fastening on one rope, such a rope may be made endless, with points of attachment for flights, buckets or carriers, for conveyors, elevators, etc. For certain sizes of ropes the fasteners have been approved by Lloyds Register of Shipping for use in ships classed, or intended to be classed, by them.

ELECTRIC HAND TOOLS.—Messrs. S. N. Bridges & Co., Ltd., Bridges-place, Parsons Green-lane, London, S.W.6, who manufacture an extensive range of electrically-driven hand tools for commercial and domestic use, showed four examples of them at an introductory cocktail party, given in the Park Lane Hotel, Piccadilly, London, W.1, on Friday, November 20. The tools shown were a ¼-in. general-purpose drill, an orbital sander, a portable jig-saw, and a floor polisher which can also be used as a drill. The tools are all operated by universal motors, so that they can be used on a direct-current or single-phase supply and are all fitted with "suppressors" to prevent interference with radio or television receivers. It was not permissible to show the tools in use, but they appeared to be well made and serviceable, and the modest prices quoted will doubtless make a wide appeal. Some examples of the complete range, which includes disc and belt sanders, polishers, bench grinders, edge planers, routers, bolt rammers and many other tools for workshop and garage use, were shown and demonstrated at the recent Building Trades Exhibition in London.

LIQUID-METAL SAMPLING APPARATUS.

THE British Steel Castings Research Association, Broomgrove Lodge, Sheffield, 10, have brought to our notice a rotary liquid-metal sampling device which, although designed for steel foundries, should find application in iron foundries and also in the heavy steel industry. The apparatus, which is based upon a design of the late Mr. S. Westberg, of Rotherham, enables furnace samples of steel or other metals to be produced in finely granulated or divided form directly from the liquid state, thus dispensing with the drilling of specimens after solidification. This is achieved by gently pouring the sample of liquid metal on to a rotating copper disc, which disperses the metal centrifugally upon the internal periphery of a surrounding metal



bowl from which the granulated sample is subsequently collected. The prevention of oxidation is necessary during the sampling operation and this is conveniently achieved by providing a high-purity nitrogen or inert-gas atmosphere in the dispersion bowl of the apparatus. As is shown in the accompanying diagram, the gas is admitted into the chambered cover plate and enters the dispersion bowl through holes in the inner surface of the cover plate.

The British Steel Castings Research Association state that they have conducted extensive field trials in order to establish the reliability of the apparatus. These have involved many analyses, of granulated and of orthodox drilled samples, of all the normal elements present in steels, and also of nickel, chromium, molybdenum and tungsten, over a relatively wide range. These trials have been conducted by the Research Association, in conjunction with Westberg Developments, Limited, Rotherham, who are now manufacturing and marketing the equipment under patents pending in the United Kingdom and overseas.

POLYTHENE-INSULATED POWER CABLE AT MANCHESTER.—An 11-kV 0·1 sq. in. three-core screened cable, insulated with polythene, has recently been laid between the Nos. 2 and 3 substations of the Manchester Ship Canal Co. and the new oil dock at Eastham. The cable is wire-armoured and served but, owing to the imperviousness of the insulating material, is unsheathed. Like the hydraulic and other services, it is laid in a 135-ft. subway under the entrance lock to the dock. It was manufactured by the Telegraph Construction & Maintenance Co., Ltd., Greenwich, London, S.E.10, in three 360-yd. lengths and both in the subway and the two vertical approach shafts is secured in greenheart cleats. Its light weight and flexibility greatly facilitated installation. The "Telecohesive" tape which has been used at the joints reproduces the non-hygroscopic qualities of the cable dielectric.

CONSERVATION OF FUEL AND POWER RESOURCES.

IN a paper on "The Conservation of the Nation's Fuel and Power Resources," which he read before the Institute of Fuel on Tuesday, November 24, Dr. F. M. H. Taylor outlined a "fuel plan," which could be adopted by the Government in order to secure maximum economy in the utilisation of available resources. In the past, he said, the coal, electricity and gas industries had put forward plans for solving Britain's fuel problem in terms of the particular type of service one or other of them had to offer the consumer. Dr. Taylor, on the other hand, was concerned to ensure that any proposals that were made for improvement should be consistent with the Government's overall economic policy and would benefit the nation as a whole. Thus, in settling what amounts of capital should be invested in the fuel-production and distribution industries and in plant for improved utilisation, account, he said, must be taken of the savings of money and coal in each case, and an appropriate list of priorities established.

The price of the coal supplied to the two competing industries—gas and electricity—had in the past been fixed by the Coal Board alone, thus permitting that body to control economic development. This practice should be modified in the national interest by making the price structure subject to independent supervision by, say, a Fuel Advisory Committee, which would ensure stable prices and the true economic development of electricity, gas and coke. The Committee would also satisfy itself that the policy of equating prices with costs of production and distribution was actually carried out. The Government's present policy of providing industrialists with financial incentives to install fuel-economy plant was commendable, but in this connection one of the most pressing problems of the day was that of the marginal coal which was produced and sold at a loss in order to satisfy the excessive demands of the more wasteful fuel users.

A fuel plan would influence major policies, trends and investments in the nationalised fuel-producing industries and those large consumers which were already under some form of State control. It would influence policy where changes of taxation within the framework of overall financial and fiscal policy were considered. The plan would also help to create a public opinion in which national and individual consumer interests were united in the achievement of substantial fuel economies. Maximum encouragement must be given to competitive enterprise and the consumers' freedom of choice, thereby relating desirable economies to the consumer's pocket, subject to the prices charged being fairly related to the true costs of supply. This plan provided a commendable alternative to schemes of allocation and direction to the consumer. Government direction on technical, apart from political grounds, was a poor substitute for the consumer's purse.

There was need for the publication at intervals of the types, grades and qualities of coal which the Coal Board expected to produce during the next five-year or ten-year period, in order to ensure that those who installed expensive plant might know in advance the fuel they could expect to receive. The constant and reliable supply of fuel to users installing special plant was necessary to avoid scrapping and loss by industry generally. The engineering institutions should publish standards of efficiency for fuel-consuming plant, so that a yardstick for efficient utilisation might be readily available. The practice of some local authorities of providing complete hot-water heating services to tenants at uneconomic prices was to be deplored as subsidising an extravagant use of fuel and fuel-saving equipment and thus aggravating the nation-wide shortage. The practice of some local authorities of providing complete hot-water heating services to tenants at uneconomic charges was criticised as an extravagant use of fuel. By the use of already well-known methods of fuel and power utilisation, substantial savings could be effected and increased supplies of heat and power made available for the urgent task of improving the productivity of British industry.

NOTES ON NEW BOOKS.

Investigations on Building Fires. Part VI.—The Fire Resistance of Reinforced Concrete Columns.

By DR. F. G. THOMAS, M.I.C.E., and C. T. WEBSTER, M.B.E., F.R.I.C. National Building Studies Research Paper No. 18. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 3*s.* net.]

THIS booklet, sixth in the series of reports on fire resistance, has been written as part of the programme of the Building Research Station, and describes investigations into the relationships between the fire-resistance of reinforced-concrete columns and the applied load, concrete strength, column size and reinforcement used. The test data and results are given in a comprehensive series of tables and diagrams. The arrangements adopted for the tests—the end loads being applied by a hydraulic press to test columns, 10 ft. long, erected within a furnace—are easily appreciated from four photographs reproduced in the report. All the columns tested were square in cross-section, varying between 8 in. and 19 in. square; the Portland-cement concrete, made with a gravel aggregate, had a cube-strength of between 2,250 lb. and 5,000 lb. per square inch at 28 days. Prior to testing, the columns were matured for periods varying from seven months to 2¾ years. Tentative relationships were obtained that coupled the mechanical properties of the concrete and steel with the fire resistance of the column. The use of limestone or blast-furnace slag as aggregate for the concrete was found to increase the fire resistance considerably. The resistance was also increased by embodying a light mesh reinforcement in the cover concrete over the main bars, to reduce spalling. An attempt to assess the fire resistance of columns from small-scale tests on concrete cylinders proved unsuccessful, but further research is now in hand to see if such tests can be made to yield a reliable estimate of the behaviour of a column.

Physics. Vol. I. Part I, Mechanics; Part II, Heat; Part III, Properties of Matter, and Sound.

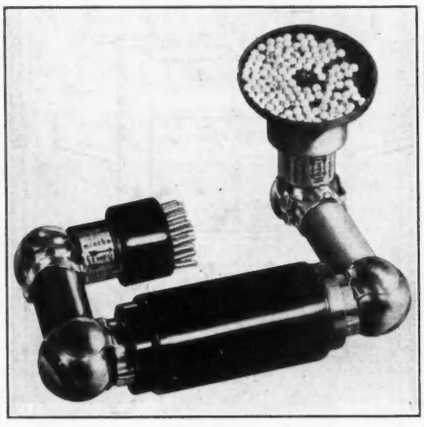
By L. S. POWELL. Sir Isaac Pitman & Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price: the three parts bound in one volume, 21*s.*; each part separately, each, 5*s.*]

THIS book covers the three-years course in mechanics, heat and sound leading to the Ordinary National Certificate in applied physics. It is intended for class use, employs no calculus, and treats the more elementary basic material which would normally be studied in the first year in greater detail than developments which would, more appropriately, be left over to the third year. Part I, on mechanics, deals with kinematics, Newton's laws of motion, composition and resolution of forces, moments, circular motion, work, energy, power and machines. Part II, on heat, presents a good treatment of heat engines. The first section of Part III is concerned with properties of matter, including liquids at rest and in motion, surface tension, viscosity and elasticity; the second section deals, necessarily sketchily, with sound. The style is informal and interesting with instances illustrating the principles drawn from a wide range of modern technical applications. The line diagrams are plentiful, clear and often amusing. Many of the laboratory experiments that would be performed in a companion practical course are described only in outline; and there is a lavish provision of examples many from past examination papers, with answers in most cases. The brief historical notes are likely to prove stimulating and many of them are followed by references to books for further reading. The publishers of these books are given in parentheses, except on pages 54 and 478, where the publisher is hyphenated on the author with somewhat startling effect.

PLUNGER PRESSURE GAUGE: ADDENDUM.—The new pressure gauge described on page 670, *ante*, is suitable for any application where a robust shock-proof gauge is necessary, not only for the Handraulic starter made by Bryce Berger, Limited, as stated in the article.

THE MINCHOM-SEMPUN MAGNETIC FLAW DETECTOR.

THE magnetic flaw detector illustrated below, which is made by R.P.R. Patents, Limited, Alexandra Palace Station, London, N.10, consists of two side links and a central member. The latter encloses a coil which can be energised from a 12-volt battery and forms the carrying handle. These parts are connected by ball links which turn in spherical sockets and are made up of three sets of laminations, one of which is of non-magnetic material. When a ball link is turned so that this non-magnetic lamination is brought into contact with its spherical seat, the magnetic field has to traverse what is equivalent to an air gap. A large part of its flux is therefore absorbed and the effect between the pole shoe brushes is reduced. Each of these brushes contains 45 contact pins which move automatically and independently of each other perpendicularly to the face. The magnetic circuit is completed by a keeper bridge link. By bringing one or more of the non-magnetic laminations into contact with the spherical seats of the members and brushes, varying values of magnetic force can be obtained, the range being from 100



oersteds across a 2 in. gap to more than 350 oersteds. An even larger force can be obtained by omitting the side links and connecting the pole shoe brushes directly to the central member.

To operate the detector a check test-piece is used. This consists of a length of mild steel in which surface cracks are simulated by four holes. These holes after drilling are plugged and burred and are further concealed by a thick coat of white enamel on one surface. Flaws near the surface are simulated by other small holes, which are drilled at different depths from the sides to central clearance holes. The detector is set so that the pins of the brushes are in contact with the ends of the check test-piece and ink is sprayed on to the white enamelled surface. If the instrument is in working order, the flaws will then be clearly indicated. The contact brushes are next placed one on either side of the piece which is actually to be tested and the area between them is flushed with flaw-detection ink. As this area becomes magnetised the flaws show up either in the form of thin black lines or local burring, these indications being facilitated by first coating the test-piece with white paint. When awkward or restricted spaces are being investigated the brushes are detached from the set and connected to the keeper bridge link, which remains set in the vertical or underslung position. When this procedure is adopted cracks show up quickly in the area between the brushes where the magnetic field is greatest, and more slowly on the fringes of this area, so that it is necessary to take time for an inspection. Although, as a general rule, the smaller the articles the less the magnetic force that should be utilised, a better guide, especially in routine testing, is to employ such force as will give clear crack indications without blurring the surface with ink.

The detector can be re-magnetised, when this is necessary at infrequent intervals, by connecting the coil through one of the leads provided to the negative pole of a 12-volt battery and then bringing the other lead into momentary contact with the positive pole. During this operation the magnetic circuit is closed through the keeper or test-piece.

BOOKS RECEIVED.

The Aircraft Engineer's Handbook. No. 1. *Airframe Structure and Controls, Flying Instruments and Equipment.* By W. J. C. SPELLER. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 30*s.* net.]

Machine Shop Practice. By W. C. DURNEY. Third edition. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 12*s.* 6*d.* net.]

Calculation, Design and Testing of Reinforced Concrete. By DR. K. L. RAO. Second edition. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 35*s.* net.]

The J. & P. Switchgear Book. By R. T. LYTHALL. Fifth edition. Johnson and Phillips, Limited, Charlton, London, S.E.7. [Price 35*s.* net.; reduced price available to students on application.]

Transport Costing. Published for a Joint Committee of the Institute of Municipal Treasurers and Accountants (Incorporated) and the Institute of Cost and Works Accountants. Gee and Company (Publishers), Limited, 27-28, Basinghall-street, London, E.C.2. [Price 2*s.* 6*d.* post free.]

A Handbook on Die Castings for the Use of Service Designers and Inspectors. By F. D. PENNY. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6*s.*]

Fire Protection Year Book, 1954. Compiled by GEOFFREY F. D. PRATT. Benn Brothers, Limited, Bouverie House, Fleet-street, London, E.C.4. [Price 12*s.* 6*d.*, post free.]

The Mechanics of Engineering Soils. By P. LEONARD CAPPER and PROFESSOR W. FISHER CASSIE. Second edition. E. and F. N. Spon, Limited, 22, Henrietta-street, London, W.C.2. [Price 25*s.* net.]

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